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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 680

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER August 14, 1918

MISCELLANEOUS CONIFERS OF THE ROCKY MOUNTAIN REGION

By

GEORGE B. SUDWORTH, Dendrologist

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SCOPE OF THE BULLETIN.

This bulletin deals with the distinguishing characteristics, forest habits, and geographic distribution of all the larch, hemlock, false-hemlock, incense cedar, arborvitæ, and yew trees that grow naturally within the Rocky Mountain region. The extent of the territory included in this region is indicated in a recent publication on "The Cypress and Juniper Trees of the Rocky Mountain Region," [1] which also contains a full discussion of the class and family relationships of the true coniferous trees here described, as well as information applicable in the present case regarding the method of treating the subject, the sources from which data on the geographic range of trees were obtained, and the like. Acknowledgments made in the above-mentioned publication of assistance received apply also in the case of the present bulletin.

Keys for the identification of genera and species are provided on page 44.

[1] Bulletin No. 207, U. S. Department of Agriculture, p. 1, 1915.

GENERIC CHARACTERISTICS OF LARCHES.

The larches,[2] some of which are also called tamaracks, belong to the genus Larix.

They lose their leaves every autumn, their branches becoming bare in winter and in the spring putting forth new foliage. The branches occur irregularly on the trunks, differing in this respect from the branches of pines, spruces, and balsam firs, which are regularly whorled. The leaves resemble somewhat those of other conifers in being needle-shaped; but they are distinct in arrangement from the remainder of our native cone bearers in being produced in little brushlike clusters, each of which contains from 12 to 40 leaves (Pls. I, II, III). These clusters are borne on all but the leading or new shoots, on which the leaves are scattered singly (Pl. III, *b*). The little budlike spurs that bear clusters of leaves are really aborted or partly suppressed branchlets, which, if conceived to be extended by growth, would show their leaves disposed singly as on the leading shoots.

Both the male and female flowers, which appear with the new leaves, are borne singly and separate from each other on the same branches or twigs of the previous or an earlier year's growth. The male, or pollen-bearing, flowers are small, budlike, rounded, or elongated, yellow-green bodies about the size of a small pea, and are borne naked. Female flowers, which produce cones and seeds, are similarly small, elongated bodies composed of tiny scales, at the bases of which are borne two minute naked ovules. The female flowers are usually a bright purple or red. They are accompanied by a bundle of leaves.

The cones mature in a single season, but they often remain on the trees for one or more seasons after maturity. Two winged seeds are borne under each of the thin fertile cone scales (Pl. III, *d*). Larch cones open in the autumn shortly after they are matured, and shed their seed. The seed-leaves (cotyledons) vary in number from 5 to 7. Succeeding these, the young stem bears single scattered leaves, just as do also the leading or young shoots from branches of old trees. Seedlings continue to bear single leaves for several years, after which they produce the adult clusters of leaves.

The larches are important timber trees. They produce straight, tall stems, the wood of which is slightly resinous, strong, and moderately durable. The largest trees supply excellent saw timber.

At least three distinct species of larch inhabit the United States. One is found mainly in northeastern United States and adjacent

[2] The name Larch (from the Latin Larix, a larch tree) is properly applied only to trees of the genus Larix. During the last 25 years, however, "larch" has been, and is still, improperly used by Pacific slope lumbermen and woodsmen as a name for the noble fir, Abies nobilis, which is a true fir or "balsam" in no way directly related to the larches. This use of the name "larch" should be discontinued, for it has led to much unnecessary confusion.

Canadian Provinces, from which it extends westward to southern Alaska. The other two species inhabit northwestern United States extending northward also into Canada. A fourth species, not now fully known, is possibly confined to Alaska.[3]

The larches are of ancient origin, several European species having existed since the Miocene period. The European larch (*Larix europæa*) appears in the upper Pliocene of Europe and is represented throughout the Pleistocene, while our eastern larch (*Larix laricina*) is common in this country during the Pleistocene period.[4]

TAMARACK.

Larix laricina (DuRoi) Koch.

COMMON NAME AND EARLY HISTORY.

Larix laricina is most commonly known throughout its range as tamarack, particularly among woodsmen. Sometimes it is also called larch, black larch, red larch, and hackmatack.

Tamarack was one of the first of our conifers to become known, the earliest report of it being as a tree cultivated in England in 1735.[5] The early French Jesuit missionary and historian Charlevoix saw the tamarack in eastern Canada and gave the first complete published account of it in 1744 [6] ("Larix canadensis, longissimo folio"). However, the earliest mention of this species is doubtless by John Josselyn,[7] who describes the great lasting qualities of a "Larch tree" observed in New England in 1667, which can be none other than our tamarack. The first technical description and (polynomial) designation [8] of tamarack was published in 1770, while the first technical binomial designation, Pinus laricina DuRoi [9] was published in 1771. The technical name Larix laricina (DuRoi) Koch, now properly maintained for this tree, was established in 1873.[10]

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[3] See Smithsonian Miscellaneous Collections, vol. 50, p. 174, Pl. XVII, 1907; Forest Trees of the Pacific Slope, p. 74, fig. 28A, 1908 (U. S. Dept. Agr.).

[4] The author is indebted for this information to Dr. Edward W. Berry, paleontologist of John Hopkins University.

[5] Aiton, Hortus Kewensis, III, 369, 1789.

[6] Histoire de la Nouvelle France (ed. 12 mo.) IV, 371, fig. 22, 1744.

[7] An Account of Two Voyages to New England, 68, 1673.

[8] "Pinus Larix Americana nigra", Muenchhausen, Hausv., V, 226, 1770.

[9] Obs. Bot., 49, 1771.

[10] William Aiton (Hort. Kew. III, 369, 1789) says that this larch was cultivated in England in 1735.

According to Loudon (Arb. et. Frut., IV, 2401, 1838), a form of this larch ("Larix a. pendula") was introduced into England by Peter Collinson in 1739, while another form ("Larix a. rubra") was introduced by the Duke of Argyle in 1760, the latter tree having attained a height of 40 or 50 feet in 77 years. Elwes and Henry (The Trees of Great Britain and Ireland, II, 394, 1907) say that modern English arboriculturists have entirely neglected this tree. Only a few trees are now known in England, the largest being from 50 to 78 feet high and from 18 to 20 inches in diameter.

Larix laricina is little used as an ornamental tree in the United States, probably because it is believed the tree can not be grown outside of its natural habitat in wet, mucky ground. It is, however, well adapted to rich, sandy or gravelly upland soils that are fairly moist and deep. Under such conditions it grows rapidly and to a large size and has a beautiful symmetrical form.

DISTINGUISHING CHARACTERISTICS.

The largest tamarack trees in the Rocky Mountain region are seldom over 50 feet high and 12 or 14 inches in diameter. Tamarack has a single straight, slightly tapering trunk, and a narrow, sharply conical crown of slender, horizontal branches, which, during the first 25 or 30 years, extend nearly down to the ground. Later the trunks are clear of branches for one-half or two-thirds of their length. The thin, scaly bark is reddish brown, but outwardly more or less weathered to an ashy brown. Twigs of a season's growth are smooth and whitish at first, but by winter they become a dull yellowish brown.

Mature leaves (the juvenile form is scattered singly on vigorous leading shoots) occur in clusters of about 12 to 20 (Pl. I), and are indistinctly triangular in cross section (convex on the top side, with a ridge beneath) and from about seven-eighths of an inch to $1\frac{1}{8}$ inches long. In cross section the leaf shows two minute resin ducts close to its edges.

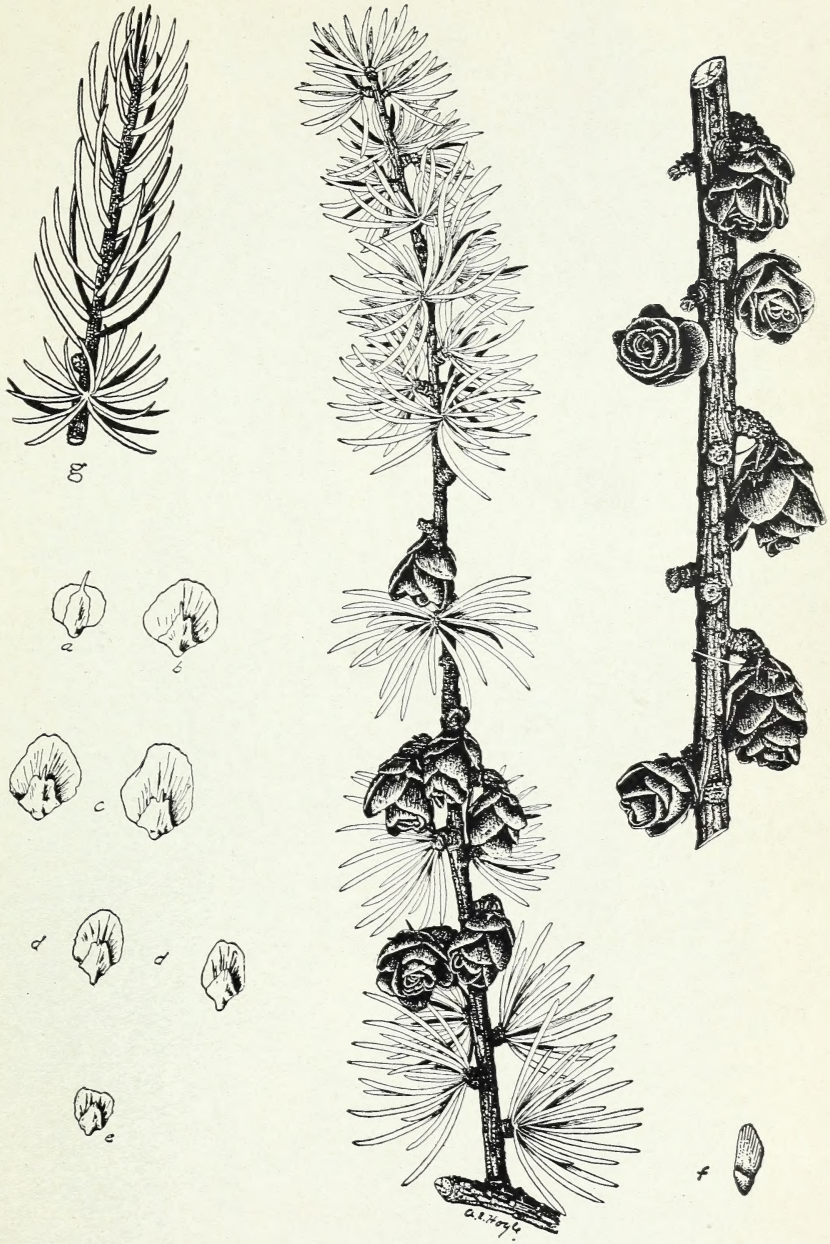
The cones (Pl. I), matured in early autumn of one season, are pale russet-brown, as are the minute-winged seeds (Pl. I, *f*), which escape slowly from the gradually opened cone scales during late autumn or early winter; the upright position of the cones doubtless prevents the seeds from escaping as rapidly as do the seeds from the pendent cones of other conifers.

Wood of the tamarack is a pale yellowish brown, and varies in texture from narrow-ringed to moderately wide-ringed, according as the trees are grown in dense or open stands. It is rather hard and heavy, durable, elastic, and fairly straight-grained,[11] a cubic foot of dry wood weighing nearly 39 pounds. Large trees have a rather thin layer of whitish sapwood, which is much thicker in young trees. The wood is used chiefly for telegraph and telephone poles and for railroad ties, the largest trees being cut for rough lumber.

OCCURRENCE AND HABITS.

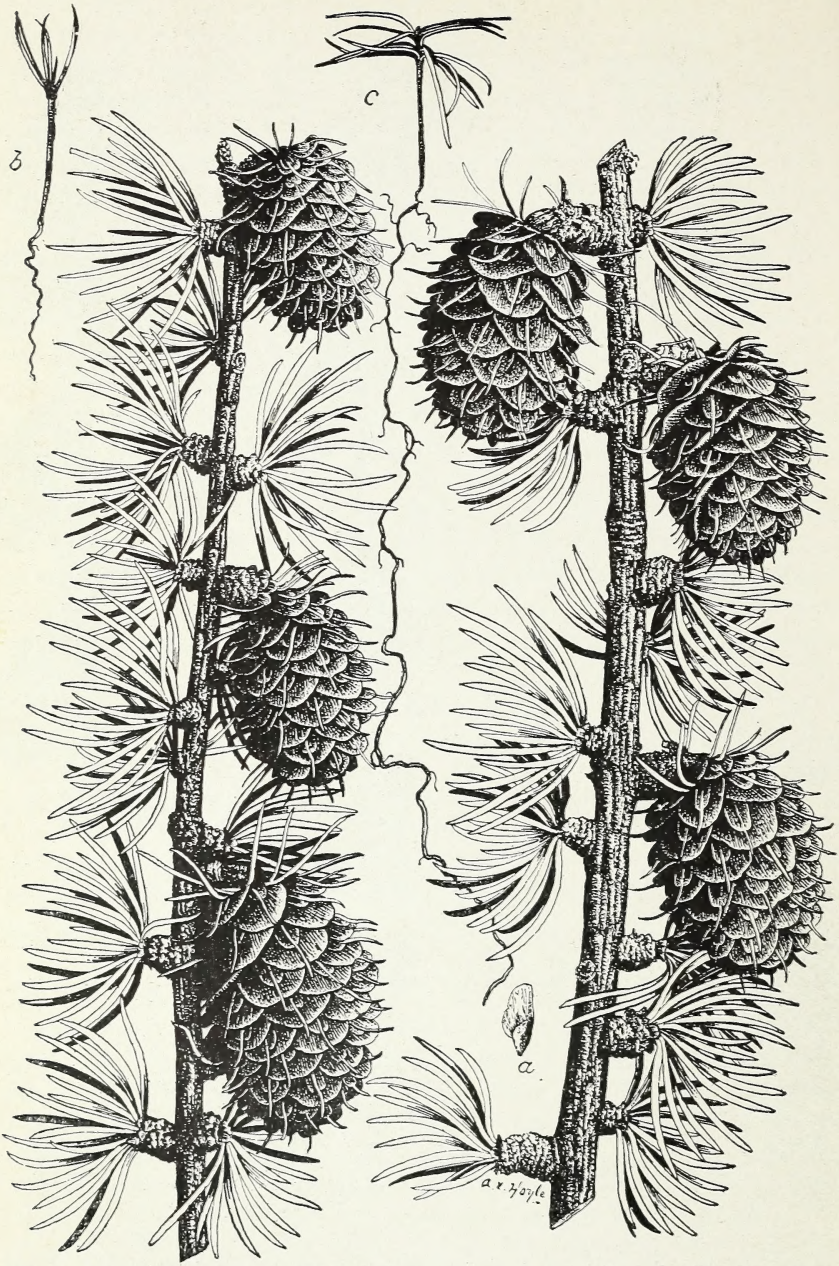
Tamarack enters the Rocky Mountain region (Map No. 1) only north of the Canadian boundary, and occurs mainly on the east side of the Canadian Rockies. It is most abundant in sphagnum swamps and muskegs; but the largest trees occur on the better-drained margins of swamps and lakes, moist, porous benches, and bottom lands. It thrives also on moist, well-drained deep-soiled hillsides. In the Rocky Mountain region the tamarack grows at elevations between about 600 and 1,700 feet; its vertical distribution elsewhere in its range is, however, imperfectly known at present.

[11] Old trees often have an outer layer, 3 to 4 inches thick, spirally twisted, within which the earlier formed trunk wood is straight-grained.



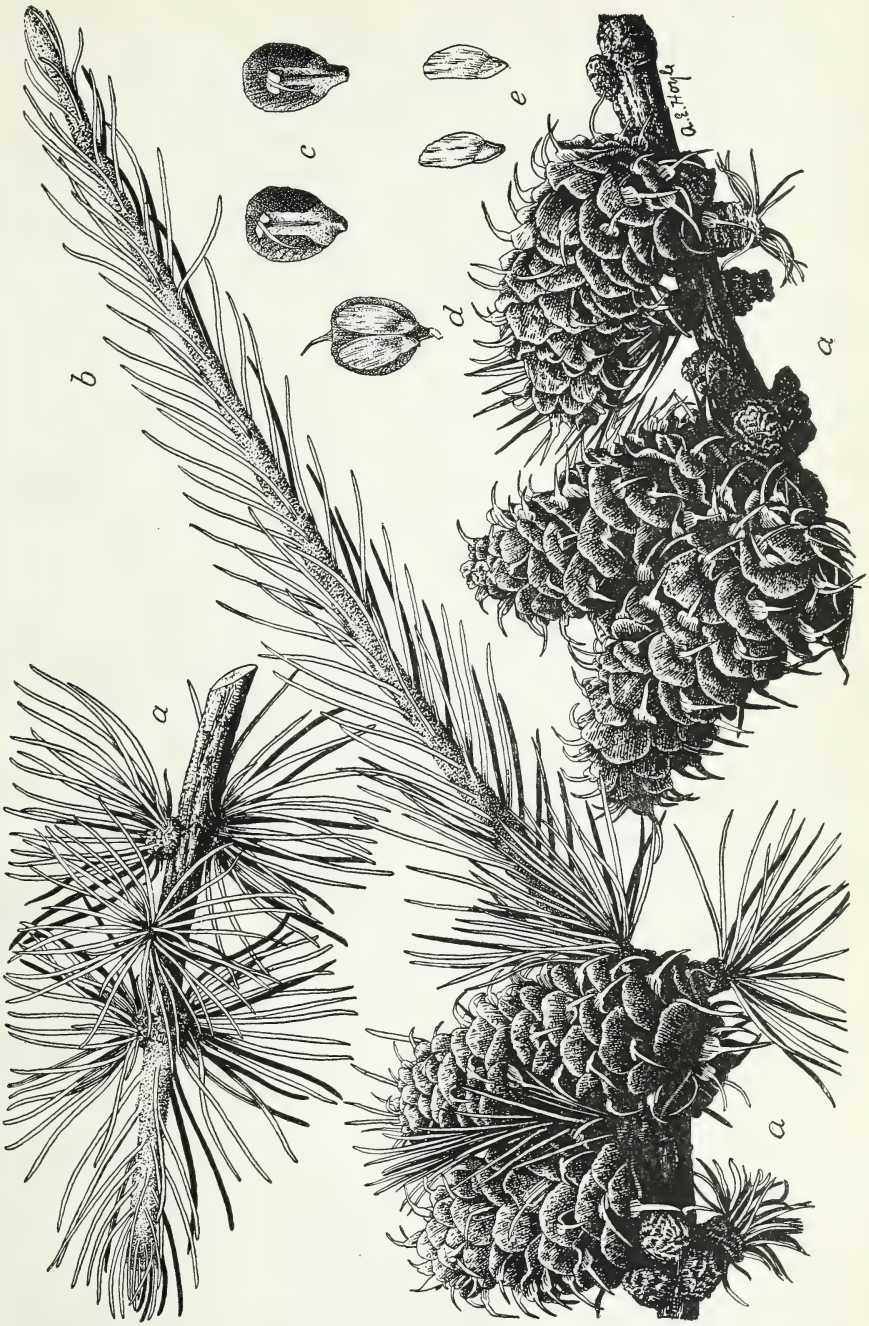
LARIX LARICINA: FOLIAGE AND LEAFLESS BRANCH WITH OLD PERSISTENT OPEN CONES.

a, Cone scale at base of cone; *b*, scale near base; *c*, scales from center of cone; *d*, *e*, scales near top of cone (all enlarged 1½ times natural size); *f*, seed with its wing (natural size); *g*, terminal shoot with juvenile or primary leaves.



LARIX OCCIDENTALIS: FOLIAGE AND CLOSED CONES.

a, Upper side of seed with wing; *b*, seedling 2 weeks old; *c*, seedling 6 weeks old.



LARIX LYALLII: FOLIAGE AND CONES.

a, Clusters of foliage and open cones; *b*, primary or juvenile leaves of new shoot; *c*, cone scales showing their protruding bracts; *d*, upper side of cone scale with its seeds; *e*, upper (left) and lower sides of seeds with wings.

The tree grows on shallow, moist soils of nearly every consistency, from stiff clay to coarse sand, but thrives on moderately retentive loams, especially those with rich leaf mold. The occurrence of tamarack in saturated soil seems to indicate not so much a special requirement as it does ability to exist where other species more tolerant of shade can not grow. Tamarack does not grow well, however, where its roots are constantly submerged, particularly during the summer season. It occurs in open scattering stands mixed with black spruce, black cottonwood, alder, and willows, or sometimes forms rather dense, pure growths of limited extent. Even in the closest stands, however, the crown cover is never very dense, for it requires a great deal of light throughout life, at no time enduring heavy shade.

Larix laricina produces seed abundantly about every 2 to 4 years, some seed being borne annually. Trees begin to bear cones at an age of from 10 to 20 years, seed production increasing rapidly thereafter up to an age of about 100 years, after which it decreases in amount and regularity. The seed has only a moderately high rate of germination and fairly persistent vitality. Conditions favorable to germination of the seed and early growth of the seedlings are fresh organic or mineral soil, with a sparse protecting cover of grass or herbs. Seedlings require this slight protection at first; afterwards in full light they grow fairly rapidly in height, so that they persist in mixture with more tolerant but slower growing species of the same age.

LONGEVITY.

The largest trees are from 150 to 180 years old; those from 10 to 12 inches through are from 60 to 75 years old.

WESTERN LARCH.

Larix occidentalis Nuttall.

COMMON NAME AND EARLY HISTORY.

Western larch is known to lumbermen and settlers in its range only as "larch," a name which is applied more or less also to other native species of Larix. The common name western larch, a literal translation of the technical name, is suggested in order to avoid confusion.

The first discovery of Larix occidentalis was made in 1806 by by Lewis and Clark,[12] whose narrative tells of finding a "larch tree," now believed to be the western larch, on the upper Clearwater River in western Montana. It is evident that the Scotch explorer David Douglas[13] was the next one to observe this tree, on the Columbia

[12] History of the Expedition under command of Lewis and Clark (ed. Coues), III, 1043, 1066, 1806.
[13] Companion Botanical Magazine II, 109, 1836.

River in the vicinity of Fort Colville, northeastern Washington, in 1827, although he believed it to be Larix europæa. It was not, however, until 1834 that the western larch was really recognized as a new and undescribed species, Thomas Nuttall having discovered the tree at that time in the Blue Mountains of northeastern Oregon. Later, in 1849, he described and named it Larix occidentalis. Since then, the history of western larch has been practically free from confusion, but one other name ("Pinus Nuttallii Parlatore," 1868), now a synonym, having been given to the tree during the long period it has been known.[14]

DISTINGUISHING CHARACTERISTICS.

Larix occidentalis is the largest and most massive of North American larches. Its straight stems grow ordinarily to a height of from 100 to 180 feet, and to a diameter of 3 or 4 feet. Not infrequently, however, trees reach a height of over 200 feet and a diameter of from 5 to 8 feet. The tapering trunks are clear of branches for from 60 to 100 feet or more. The crown is a short, narrow pyramid running up to a long slender point, and is very open, being made up of comparatively few, small, horizontal branches, which have the appearance of being thinly clad with leaves. Trees growing in protected situations at low elevations have rather long, narrow crowns, with more or less weeping branches. In exposed places at high elevations this weeping habit is much less pronounced.

Middle-aged and old trees have reddish cinnamon-brown bark, which is 3 to 6 inches thick and deeply furrowed near the base of the tree, where the ridges are strikingly massive; 20 or more feet above, it is much thinner and less deeply furrowed. The exceedingly thick bark on the lower trunks of large trees is often an effective protection against injury by fire, many of these trees having passed through several destructive forest fires without damage to their vitality. The bark of young trees and branches is thin, scaly, and dark or grayish brown.

The color of the foliage is a pale yellowish green, in late autumn becoming a bright lemon-yellow, which distinguishes the trees from their associates. The flatly triangular leaves, rounded on the back and distinctly ridged or keeled on the inner face, are from about 1 inch to sometimes $1\frac{3}{4}$ inches in length. In cross section they show a

[14] Western larch was first introduced into England in 1881 and again in 1889, only 1 of 40 seedlings received in 1881 surviving, and but 2 out of 10 received in 1889. Elwes and Henry (The Trees of Great Britain and Ireland, II, 396, 1907) say that in 1906 these trees measured, respectively, 33 feet in height and $5\frac{3}{8}$ inches in diameter, and 29 feet in height and $5\frac{1}{8}$ inches in diameter.

Larix occidentalis was cultivated for the first time in eastern United States, near Boston, in 1881, the trial being made with wild seedlings obtained from Oregon. Prof. C. S. Sargent says (Silva, XII, 13, 1898) that these plants have remained stunted, which would seem to indicate that the species is not adapted to the climate of New England. However, twigs from them grafted on the roots of Japanese larch have grown vigorously. We do not know of any other trial of western larch in the East. The great difficulty, however, in obtaining seed doubtless explains why so little has been done to test this tree in the East.

single fibrovascular bundle in the center and no resin ducts. The number of leaves in a cluster (Pl. II), which can not be depended upon as a distinctive characteristic, ranges from 14 to about 30.

The cones (Pl. II) mature in one season, being ripe during the latter part of August and early in September. They open soon afterwards and shed their light chestnut-brown seeds (Pl. II, *a*). By the end of October or November all of the cones have fallen from the trees. The cones are borne on very short footstalks and vary in length from about 1 inch to 1½ inches. The cone scales are usually densely coated on the outside below the center with delicate, whitish, woolly hairs. The seed-leaves of western larch are, as a rule, 6 in number (Pl. II, *b*, *c*).

The commercially valuable wood is of a clear reddish brown color, and usually narrow-ringed, with a comparatively thin layer of whitish sapwood. It is strong, and very durable in an unprotected state, differing greatly in the latter respect from wood of the eastern larch (*Larix laricina*). Western larch wood is much used locally for lumber and for rails and shakes. The largest general use, however, is for telegraph and telephone poles, railway ties, and posts. It is the heaviest of our larch woods, a cubic foot of the dry wood weighing a little over 46 pounds.

OCCURRENCE AND HABITS.

Larix occidentalis grows on mountain slopes, preferring north and west exposure, stream bottoms, valleys, and flats at elevations between about 2,000 and 7,000 feet. It is rare in the bottoms of canyons and on the summits of mountains (Map No. 2).[15] As the tree is very exacting in its requirements of soil moisture, the best growth occurs in deep, fresh, porous soils; it will, however, maintain itself in low, moist places and in dry, gravelly soils.

Western larch sometimes forms pure stands, but it usually occurs mixed with other trees. Its best growth is in northeastern Washington, northern Idaho, and northwestern Montana, where it often occurs in pure open forests in valleys and on slopes. Trees of largest size are found at lower elevations along Priest River (Idaho) in mixture with western white pine, western red cedar, Douglas fir, western hemlock, Engelmann spruce, and lowland white fir. Somewhat higher up it becomes an important part of Douglas fir forests, here being associated with lodgepole pine, western white pine, lowland white fir, alpine fir, and Engelmann spruce. In the Bitterroot Mountains (northern Idaho), it grows in pure stands or is mingled with small numbers of Douglas fir and western yellow pine.

Western larch is very intolerant of shade throughout life, probably demanding even more light than western yellow pine. The dis-

[15] The author's cordial thanks are due to Dr. H. N. Whitford for valuable notes extending the range of Larix occidentalis in British Columbia.

advantage of this intolerance is partly overcome by early rapid height growth, which carries the tree above its suppressing heavier-foliaged associates. It appears to be more tolerant on moist soils than on dry ones. In moist sites it occurs in fairly dense stands, and the trees are tall and with clear boles, but the lower branches are early killed and dropped; on drier soils, where open stands or isolated trees are more common, the branches are often retained for many years down to the ground.

Western larch is a prolific seeder, but it is locally variable in seed production, sterile periods of one or more seasons being common. It rarely bears seed as early as the twenty-fifth year, but begins to produce it abundantly when 40 or 50 years of age. The seed has a fairly high rate of germination and moderately persistent vitality. The thin scales of ripe cones open and close readily with alternate dry and wet weather, so that the period and the rapidity of seed dispersion vary somewhat with local climatic conditions. Usually, much seed is shed on the snow. Abundant moisture in the soil is required for germination of the seed and growth of the seedlings. The chief competitor of larch is lodgepole pine, the soil conditions for the reproduction of these trees being very similar, as is shown by their frequent association. Both find suitable seed beds in burned-over areas with exposed mineral soil, where the order of reproduction frequently depends upon whether the larch or pine has seeded the ground first. If lodgepole pine has the start, it shades out the much more intolerant larch. If both species start together, larch may preserve its numerical importance in the stand by more rapid height growth. Its light foliage can not prevent the growth of the pines, nor of spruce and firs, the typical occurrence of larch under these circumstances being in mixed stands. Favorite areas for pure larch reproduction are those so thoroughly burned over as to preclude the immediate heavy reproduction of lodgepole pine.

LONGEVITY.

Western larch is a long-lived tree, attaining an age ordinarily of from 300 to 500 years, while the largest trees are from 600 to 700 years old. Trees from 16 to 25 inches in diameter are from 225 to 300 years old.

ALPINE LARCH.

Larix lyallii Parlatore.

COMMON NAME AND EARLY HISTORY.

Larix lyallii is a little-known species, which is usually not distinguished by the ordinary observer from Larix occidentalis, most travelers in its high mountain habitat recognizing it only as a "tamarack" or "larch," while some have supposed it to be only a high

high mountain form of the western larch. A very few people know it as "woolly larch," a name suggested on account of the woolly young twigs. The book name "Lyall's larch," coined directly from the technical name of the tree, seems not to have gained current use. The common name alpine larch is very appropriate because it refers to the tree's characteristic alpine habitat near timber line, and may serve roughly to distinguish it from the closely related western larch.

Alpine larch was discovered on the Cascade Mountains[16] in 1860 by Dr. David Lyall, surgeon and naturalist to the International Boundary Commission which surveyed and determined the boundary between British Columbia and the United States from the Gulf of Georgia to the crest of the Rockies. In 1863 it was technically described and named Larix lyallii Parlatore, a name which has been maintained for it practically throughout the 50 years this tree has been known to science, but one other technical name, Pinus lyallii Parl., now a synonym, having been applied to it during this time.[17]

DISTINGUISHING CHARACTERISTICS.

Alpine larch usually is stunted in appearance, attaining a height of from 30 to 50 feet and a diameter of from 10 to 24 inches. Exceptionally large trees, sometimes found, are from 60 to 80 feet in height and 3 feet or more in diameter. The long, broadly pyramidal, open, pointed crown is often unsymmetrically developed, some of the branches being very long and big. As a rule, the ends of the branches turn upward, but frequently they droop consipcuously. In contrast to the brittle branches of western larch, they are tough and withy. A notable characteristic of the new shoots (Pl. III, *b*) is their dense coating of white, fine wool, which is retained, more or less, for two seasons, and from which the tree gained the name of "woolly larch."

The trunks are clear of branches for only about one-third or one-half the tree's height, and, as a result of exposure to strong winds, are often crooked or bent. The bark of mature trees is rarely more than seven-eighths of an inch thick. It is indistinctly furrowed, the irregular, flat ridges of loose scales being of a deep purplish or reddish brown color, while the smooth bark of the branches is an ashy gray, as is that of young trees, on which the bark is usually unbroken until they are 5 or 6 inches in diameter.

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[16] Lyall, Journal of Linnæan Soc., VII, 143, 1864. Dr. Lyall does not say whether he found this larch in the Oregon or Washington Cascades.

[17] Larix lyallii appears not to have been introduced into cultivation as yet either in Europe or in this country. However, the very great difficulty of obtaining seeds, because the tree grows only in rough mountainous sections not easily accessible, may partly account for this. The seeds are shed soon after they are ripe, and to secure them the collector must be on hand just prior to this event. Whether or not Larix lyallii can be grown successfully outside of the severe climatic conditions of its natural range is to be determined only by actual trial. It has little of special beauty in form or appearance to commend it for ornament over other native and exotic species now in cultivation, the chief interest in attempting to grow it being its unique botanical characteristics.

The foliage of alpine larch is a light, bluish green, turning bright lemon-yellow in autumn, after the first sharp frost. The tree is then readily detected by this color on distant high, inaccessible peaks and crests. The juvenile or primary form of leaf grows singly on new shoots. The adult leaves occur in clusters of from 30 to 40 or more. They are somewhat indistinctly 4-angled, and from about 1 inch to $1\frac{5}{8}$ inches in length (Pl. III, *a*). A cross section of the leaf shows two resin ducts, one in each of the two smaller angles.

The cones mature in one season, ripening early in August, and opening soon afterwards to shed their seed. By late autumn most of the cones have fallen from the trees, a few sometimes remaining until early winter. They are from about $1\frac{1}{2}$ to 2 inches long (Pl. III). The bristle-pointed bracts (Pl. III, *c*) that project from among the cone scales are a deep purple, while the cone scales are a deep purple-red. Their margins have a fringe of tangled, very fine white wool, which is also more or less spread over the outer surface of the scales. Mature seeds (Pl. III, *e*) are pale reddish brown. The seed-leaves are usually 5 in number.

The wood of alpine larch is of a clear red-brown or deep orange-brown color, with a thin layer of whitish sapwood. It is narrow-ringed, hard, and tough. It ranks second in weight among our native larch woods, a cubic foot of dry wood weighing about 44 pounds. While the wood is suitable for rough lumber, railway ties, and mine timbers, it is not used for these purposes, probably because of the generally small size of the tree and the fact that it grows only in rough, comparatively inaccessible places.

OCCURRENCE AND HABITS.

Larix lyallii inhabits high mountain slopes and plateaus at and near timber line at elevations between about 4,500 and 7,600 feet (Map No. 3). The tree shows a preference for northern aspects and often for "passes," sheltered sides of crests, and high divides. Its environment is one of heavy snowfall, which comes early and remains well into the summer, or, in some parts of its range, throughout the year. It is very moderate in soil requirements, growing in the rockiest soil and even in crevices of rough granite slopes, provided there is abundant moisture. For the most part, alpine larch occurs in small, pure groves, or sometimes in open stands with white-bark pine, mountain hemlock, alpine fir, and Engelmann spruce. It appears to be hardier than these alpine associates, ascending higher than they do in moist basins and showing greater vigor; while its thin foliage, compact, strong trunk, tough branches, and firmly anchored roots enable it to withstand without serious damage the rigors even of high bleak summits.

Like the western larch, this alpine species is very intolerant of shade throughout its life. Little is known now regarding its seeding habits. Sometimes cones are produced abundantly, but apparently at infrequent and irregular intervals. Reproduction in the United States is generally scanty, seedlings never being numerous, which may be due to the fact that much of the seed falls on the snow and is carried away during spring floods.

LONGEVITY.

Alpine larch is a long-lived tree, attaining an age of from 400 to 600 years. Exceptionally large trees are doubtless 650 to 700 years old, or even older, the exact age limits being imperfectly known at present. Trees from 16 to 18 inches in diameter are from 470 to 510 years old.

GENERIC CHARACTERISTICS OF HEMLOCKS.

The hemlocks, which belong to the genus Tsuga, are evergreen trees with soft, flat, or rounded-triangular leaves (Pls. IV and V). Their branches grow from the trunk at irregular intervals, differing in this respect from the pines, spruces, and balsam firs, the branches of which occur in regular whorls. The slender terminal sprays of the hemlocks droop gracefully, and the slender leaders nod conspicuously from the tops of the crowns. Hemlocks are large trees with broad pyramid-shaped crowns and long, slightly tapering trunks, which have characteristically rough, hard bark narrowly ridged and furrowed. The bark contains tannin, which gives it an astringent taste, and when broken it displays a clear chocolate-red color.

The leaves, which have small, threadlike stems, are spirally arranged around the twigs. According to the form of the leaves and size of the cones our native hemlocks are divided into two groups. One group has rounded leaves, so arranged that they completely cover the upper side of the twigs, and large cones (Pl. V); while the other group has flat leaves so arranged that they appear to grow only from two opposite sides of the twigs, the cones of this group being comparatively small (Pl. IV). A twist in the stem of the leaves brings them into the characteristic positions described. The leaves of hemlocks are peculiar in having but one resin duct, which, as seen in a cross section of the leaf, is situated in the center of the leaf near the lower surface. Leaves of a season's growth remain on the trees for from about 3 to 6 years, giving the twigs a well-covered appearance.

The male and female flowers are borne separately on different parts of the same tree, on twigs formed the preceding season. The female flowers grow at the ends of the twigs, while the male flowers are borne singly from buds at the bases of the leaves near the ends of the branchlets. Female flowers, which produce cones and seed, are small, greenish, scaly bodies, while the male flowers, pollen-

bearing only, are small yellowish bodies attached by threadlike stems. The cones of the hemlocks mature in one season, and are composed of thin overlapping scales, beneath each of which two winged seeds are borne (Pl. IV, *a*); only the scales in about the central half of the cones, however, bear fertile seeds, those above and below this part being imperfect. The seeds of hemlocks are peculiar in having minute resin cells at various points on the outer surface. The small light seeds are easily wafted by the wind and thus may be widely disseminated. The seed-leaves of our native hemlocks are from 3 to 4 in number and very short.

Hemlocks are important forest trees, both for saw timber and for tan bark. As yet their wood is of comparatively lower commercial value than that of the pines, firs, and spruces, which often grow with hemlocks. Unquestionably, however, the commercial importance of hemlock wood, particularly of the western hemlock, will be greatly increased as the supply of other timbers, abundant now, is reduced. Strangely enough, the superior quality of western hemlock timber has long failed to be fully appreciated because the wood has been assumed to be similar in quality to that of the eastern hemlock, to which the western wood is vastly superior.

Four species of hemlock are indigenous to the United States and adjacent portions of Canada. Two of these inhabit eastern United States and adjacent Provinces of Canada, and two are found in the north Rocky Mountain and Pacific forests.

The hemlocks are of ancient origin, remains of them having been found in the Miocene formation of Europe and Asia. Tsuga mertensiana, the mountain hemlock, has been found in the Pleistocene of Alaska.[18]

WESTERN HEMLOCK.

Tsuga heterophylla (Raf.) Sargent.

COMMON NAME AND EARLY HISTORY.

Western hemlock is known to laymen chiefly as "hemlock." From its very close general resemblance to the familiar eastern timber hemlock (*Tsuga canadensis* Carr.) many of the early settlers in the Northwest believed the western hemlock to be the same as the eastern species. The common name "western hemlock" is here adopted in order to prevent confusion of these trees, which are botanically distinct and, as northwestern lumbermen well know, very unlike in the qualities of their woods.

The British navigator George Vancouver gives the first published notice of this tree in 1798, in his narrative of a voyage [19] to the north Pacific coast, in which he mentions "the Canadian and Norwegian hemlock," a name that can refer only to the species we now know

[18] Fide Dr. Edward W. Berry; see footnote No. 4.

[19] Voyage of Discovery to the North Pacific Ocean and Round the World (1798).

as Tsuga heterophylla. He first observed the tree on the shores of Puget Sound in 1792.

The first technical name, "Abies heterophylla Rafinesque," applied to western hemlock, was published in 1832. The present accepted name, Tsuga heterophylla (Raf.) Sargent, which is based on that of Rafinesque, was, however, not established until 1898. From 1867 to the latter date western hemlock was generally known to botanists as "Tsuga mertensiana Carrière," which was published in 1867. But this name, which is based on "Pinus mertensiana Bongard" (published in 1831), Prof. C. S. Sargent has shown must be applied to our mountain or black hemlock.[20]

DISTINGUISHING CHARACTERISTICS.

Western hemlock is a large forest tree. Its tall, clean, smooth-looking trunks, fine foliage, and drooping branchlets distinguish it from all of its associates. The trunks taper very gradually. As a rule, the base of the trunk is not greatly enlarged, but many trees from seedlings grown on logs and stumps are irregularly buttressed. Forest-grown trees have small, narrowly pyramidal crowns of slender branches, and are from 125 to 175 feet high and from 2 to 5 feet in diameter. Occasionally trees are found which are nearly 200 feet high and 8 or 9 feet in diameter. The bark of the larger branches and young trees is thin, finely scaly, and russet-brown; that of old trunks is about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick, hard, deeply furrowed, and of a dark, russet-brown color tinged with red; the main wide, flat ridges are irregularly connected with one another by narrower diagonally disposed ridges.

In color the foliage is a deep, glossy yellow-green. It clothes the twigs thickly, but has a rather thin appearance because of the small size of the leaves. The leaves (Pl. IV) appear to grow mainly from two opposite sides of the branchlets—somewhat like the teeth of a comb. They are flat, with a central groove on the upper side, have rounded ends, and short, distinct, threadlike stems, and vary in length from about one-fourth to seven-eighths of an inch.[21] The

[20] Western hemlock was introduced into cultivation in Scotland by John Jeffrey in 1851 (Malcolm Dunn, in Journ. Royal Hort. Soc., XIV, 78, 1892). Mr. Dunn (op. cit.) states that this tree was soon afterwards planted elsewhere in the British Isles, where it generally seemed perfectly at home. The large number of trees located by Mr. Dunn vary in age from about 20 to 40 years and in height from 35 to 72 feet, with diameters ranging from 15 to 25 inches. According to Elwes and Henry (The Trees of Great Britain and Ireland, II, 236, 237, 1907, under "Tsuga albertiana") the largest tree in England is said to have been planted in 1856, and in 1907 was $94\frac{1}{2}$ feet high and about 33 inches in diameter. Western hemlock is said to thrive also in temperate parts of Europe. A trial of this hemlock is being made at the Letchworth Park Forest and Arboretum, Wyoming County, N. Y. Seedlings raised from seed planted there in 1914 have survived two winters and appear to be hardy.

[21] The German dendrologist Beissner has described (Handb. Nadelh., 404, 1891) a garden form of the western hemlock as "Tsuga mertensiana macrophylla," which he distinguished by its longer and broader leaves. This form, which originated in France, appears not to be cultivated in the United States. Owing to the fact that a similar broad-leafed form of our eastern hemlock (*Tsuga canadensis*) was previously named "macrophylla," this garden form of the western hemlock was renamed Tsuga heterophylla latifolia Sudw. in 1898. Another garden form, with silvery-white young shoots, doubtless originated in a European nursery, and as yet unknown in cultivation here is "Tsuga mertensiana argenteo-variegata Hort." (Beissner, op. cit., ed. 2, 94, 1909).

leaf-bearing twigs, especially the newly formed ones of the season, are more or less minutely hairy.

The small, few-scaled cones (Pl. IV), which nod from the tips of branchlets, mature from the middle to the end of August. Their scales open rapidly afterwards and usually shed the small, winged seeds during September, or occasionally somewhat later. By spring most of the cones have fallen from the trees. Mature cones are from about three-fourths of an inch to sometimes nearly $1\frac{1}{4}$ inches long, and of a reddish clay-brown color. The cone scales, peculiar in being sharply narrowed from about their middle, are faintly downy on their outer surfaces. The seeds (Pl. IV, *a*) are light brown. The comparatively large-winged seeds are easily borne by the wind to a considerable distance from the parent tree. Seed-leaves, which vary in number from 3 to 4, are about one-fourth of an inch long. By the third year, seedlings produce foliage like that of the adult tree (Pl. IV, *b*).

Western hemlock wood is narrow-ringed and of a pale yellowish brown color, with a slight tinge of red. It is rather soft ("works" like soft pine), and in texture is very unlike the slivery wood of its eastern relative, Tsuga canadensis, which it otherwise resembles. It is the heaviest of our native hemlocks, a cubic foot of dry wood weighing about 32 pounds. The unfounded prejudice, still existing to some extent, against western hemlock wood is exceedingly unfortunate, because the best grades of this wood are useful for many of the commercial purposes for which pine is used, while the bark of western hemlock yields a much higher percentage of tannin than that of the eastern hemlock (*Tsuga canadensis*), so long and extensively used for tanning leather.

OCCURRENCE AND HABITS.

Tsuga heterophylla is a tree of the middle, moist forest zone, growing from sea level to 7,000 feet elevation (Map No. 4). It is more abundant on the west slopes of mountains than on the east slopes, being absent from the dry inland basins of Oregon, Washington, and British Columbia, but reappearing on the west slope of the Rocky Mountains. The largest trees occur on lower slopes, flats, stream bottoms, etc., on the west slope of the Cascade Mountains and on the coast ranges of Washington and British Columbia. It grows at higher elevations at the south in Washington, Oregon, and California than it does toward its northern limit in Alaska. Likewise, it occurs at lower elevations on the coast mountains than in the Cascades and on the west slope of the Rockies. With abundant atmospheric and soil moisture, western hemlock thrives in poor, thin soils and on any exposure, but it grows best on deep, porous, moist soils. Quality of the soil and exposure become much more important with a decrease

in moisture. In dryish poor soils, it seeks chiefly cooler, northern aspects. Lack of soil and moisture produces stunted growth, as do also high elevations, even when abundant moisture and good soils are present.

Western hemlock is usually a subordinate species in association with other trees; but sometimes forms the dominant growth, especially in its far northwestern range, where occasional pure stands also occur. Generally it is scattered in patches, groups, or singly through the forest. From the Pacific coast to the Rocky Mountains its common associates are Alaska cypress (Pacific region), Douglas fir, western red cedar, lowland white fir, silver fir (Pacific region), western white pine, Engelmann spruce, lodgepole pine, and western yew. It is occasionally associated with mountain hemlock.

Tsuga heterophylla is extremely tolerant of shade throughout its life, especially during the seedling stages. In later life, however, vertical light is necessary for the best growth. Prolonged suppression in dense shade greatly checks growth; but when overhead light is admitted, the trees recover remarkably well from long suppression and soon increase their rate of growth. Western hemlock maintains dense stands when growing alone, subordinate to others, or as the dominating tree with equally tolerant or slow-growing species. The ability of this tree to grow throughout its life in the densest shade explains the often almost pure stands that have followed the removal of the older forest in which hemlock was widely but only sparingly represented. The hemlock seedlings had covered the shaded ground in this older forest, and later excluded other less tolerant species trying to come in after the old trees were removed.

Western hemlock is a very prolific seeder, reproducing itself freely everywhere under favorable conditions. Trees 25 to 30 years old may begin to bear seed. Some seed is produced every year, but heavy seed years occur at irregular intervals of from two to three years. The seed has only a moderate rate of germination and fairly persistent vitality. Germination is excellent and growth of seedlings good on wet moss, humus, litter, decaying wood, muck, and mineral soils, the latter being less favorable than a seed bed of moist vegetable matter. In the dense, moist forests in which this tree grows best, its numerous seedlings are a familiar sight on moss-covered stumps and logs—often lodged high in the air—and even in the moss on living trunks. Not infrequently seedlings extend their roots through or over these decaying stumps or logs into the soil and become firmly rooted; many others, unable to do this, die.[22] Reproduction occurs abundantly under the dense shade of mature stands and also in the

[22] Mr. F. H. Conant, of Auburn, Wash., an old timber cruiser, says in a letter to the writer under date of Feb. 12, 1909, that during logging operations in (sec. 15, T. 21 N., R. 8 E.) west Washington a 240-year-old western hemlock was cut that had grown upon the prostrate trunk of an old Douglas fir.

open on cut-over areas where the forest floor is moist. Burned-over areas, as a rule, are restocked only sparingly at first by this species, because such light-demanding trees as Douglas fir, pine, larch, fir, etc., come in first.

LONGEVITY.

Western hemlock is a long-lived tree, which grows slowly in height and diameter. Trees 16 or 17 inches in diameter are from 195 to 200 years old. Large trees are from 300 to 500 years old, and it is believed that very much older trees will be found.

MOUNTAIN HEMLOCK; BLACK HEMLOCK.

Tsuga mertensiana (Bong.) Sargent.

COMMON NAME AND EARLY HISTORY.

Tsuga mertensiana is known to few people except botanists and woodsmen who travel in its high mountain habitat. The woodsmen and settlers often call it "spruce hemlock," probably because of its remote resemblance to the spruces and likeness to the well-known western hemlock of lower altitudes. "Black hemlock" is a common name often applied to it, probably on account of the notably dark green foliage. "Mountain hemlock" would seem to be a most appropriate name for this species, because it refers to the characteristic habitat of the tree.[23]

Tsuga mertensiana was first discovered in 1827 on Baranoff Island (off the northwest coast of British Columbia) by the German explorer and naturalist, Karl Heinrich Mertens,[24] in honor of whom this species was technically named for the first time "Pinus mertensiana Bongard" in 1832, and on which the present accepted name, Tsuga mertensiana (Bong.) Sargent, is based. It was next found in 1851 by John Jeffrey "on the Mount Baker range of mountains" (south of Fraser River) in northern Washington.[25] Mountain hemlock was found for the first time in our Rocky Mountain region by Dr. Sereno Watson, who discovered it in Idaho, in 1880. Mr. H. B. Ayres next reported it in northern Montana, in 1893.[26] The botanical history of mountain hemlock is complicated by a large synonymy including some sixteen different botanical names which various authors have applied to it during the 80 years this tree has been known to

[23] The application in 1867 of the technical names "Tsuga pattoniana Sénéc." (based on "Abies pattoniana Balf.," published in 1853), and of "Tsuga hookeriana Carr." (based on "Abies hookeriana Murray," published in 1855), gave rise to such book names as "Patton's spruce" and "Hooker's hemlock," which are still maintained for this tree by European writers, but which have not gained current use in the native range of the species.

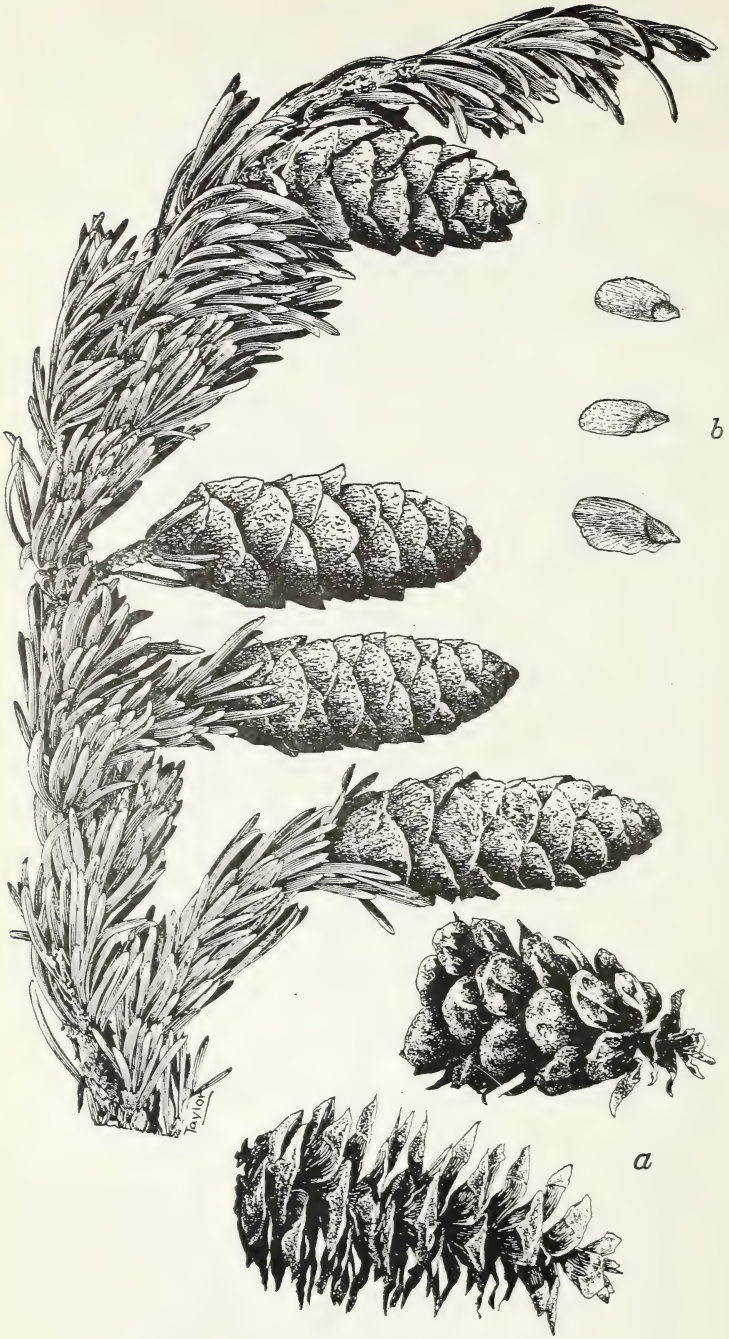
[24] "Voyage autour du Monde exécuté par ordre de sa Majesté l'Empereur Nicolas I. sur La Carvette Le Sémiavine dans les Années, 1826, 1828 et 1829, par Frédéric Lutki," III, 337 (fide Sargent, Silva XII, 80, 1898).

[25] "Jeffrey's Report to the Oregon Committee," 1852.

[26] Fide Sargent, Silva XII, 79, 1898.

TSUGA HETEROPHYLLA: FOLIAGE AND OPEN CONES.

a, Seeds with wings; *b*, seedling 3 years old.



TSUGA MERTENSIANA: FOLIAGE AND CLOSED CONES.

a, Detached open cones; *b*, seeds with wings.

science. From 1867 to 1898 mountain hemlock was known to most botanists as "Tsuga pattoniana Sénéclauze," at the close of which period Prof. C. S. Sargent showed Tsuga mertensiana to be the correct designation.[27]

DISTINGUISHING CHARACTERISTICS.

Mountain hemlock has little general resemblance to the better-known western hemlock. Only its drooping slender branches and its bark suggest hemlock to the casual observer, by whom its foliage might be easily mistaken for that of a spruce or, possibly, of a fir. Forest-grown trees have sharp-pointed, narrowly pyramidal crowns of slender, conspicuously drooping branches; the upper third of the crown has very short drooping branches, while the exceedingly slender whiplike leaders are gracefully pendulous. Trees grown in the open bear branches of the same habit down to the ground, rarely losing them for more than a few feet above ground, even in old age. Ordinarily, mountain hemlock is short, from 25 to 60 feet high and from 10 to 20 inches in diameter; on bleak crests, it is only a few feet high or sprawling on the ground. Trees 75 or 80 feet high are not uncommon, while trees 100 or 150 feet high, with a diameter of 30 or 40 inches, are sometimes met with. The trunk is often rather sharply tapering. On high steep slopes the trunks have a conspicuous bend at the base in the form of a sled runner. This is produced by heavy snows which annually bend or crush the slender seedlings and saplings to the ground without killing them. Later growth fails to straighten entirely the bent stems. The bark is early broken and rough on young trees. That of old trees is about $1\frac{1}{4}$ inches thick and of a dull purplish to dark reddish brown color. It is deeply and narrowly furrowed, the rough, hard, distantly connected ridges being narrow and rounded. At some distance the trunks have a blue-gray tinge.

The dense foliage varies from a dark to a pale blue-green. Foliage of a season's growth is shed about the fourth year. The blunt-pointed leaves (Pl. V) are rounded and plump looking, being unlike the flat, grooved leaves of other hemlocks in this respect, but like them in having small distinct stems. The leaves clothe the branches all around, but appear thicker on their upper sides. The main branchlets are unique in having numerous short, erect side twigs; both are minutely downy for several years.

[27] Mountain hemlock is said to have been first introduced into cultivation in Scotland from seeds collected by John Jeffrey "on the Mount Baker range of mountains" in 1851 (Murray, Edin. New. Phil. Journ., 289, 1855; Proc. Hort. Soc. II, 202, 1863). The bluish-leafed form of this tree cultivated for ornament in European gardens has been named "Tsuga pattoniana argentea Beissner" (Handb. Nadelh., 410, 1891), this name being changed to "Tsuga mertensiana argentea (Beissn.) Sudw." in 1898. Elwes and Henry (The Trees of Great Britain and Ireland, II, 231, 1907) have distinguished a garden form with "greenish foliage" as "Tsuga pattoniana, var. Jeffreyi," stating that it is known only in cultivation.

The cones become full grown in one season. They are usually so abundant as almost to cover the branchlets and to bend them down with their weight. When mature the cones are pendulous; very rarely, and then chiefly on stunted trees in exposed situations, are they erect when mature. They vary greatly in length from about one-half an inch to 3 inches; commonly, they are about 2 inches long and three-fourths of an inch thick before opening (Pl. V). There is great variation in the color of cones at maturity, this ranging from yellowish green to a bluish purple. Different trees of the same forest may each have differently colored mature cones; but the color is a transient characteristic and there is no other difference between such trees. When the cones open, and for some time afterwards, they are of a dull to light brown color, the scales spreading at right angles to the cone axis (Pl. V, *a*) or being strongly bent downward. After the seeds are shed, usually late in September or October, the cones begin falling from the trees, and by spring most of them are down. The pale brown seeds (Pl. V, *b*) are provided with large wings which enable the wind to carry them for long distances. Seed-leaves of the mountain hemlock are four in number, and about one-fourth of an inch in length.

The wood of mountain hemlock is very narrow-ringed, soft, and of a pale reddish brown color. It is without the silvery character peculiar to our eastern hemlock wood. It ranks second in weight among our native hemlocks, a cubic foot of dry wood weighing about $27\frac{3}{4}$ pounds. It is practically never used for commercial purposes, and locally only occasionally on the prospector's camp fire or for his rough-log cabin.

OCCURRENCE AND HABITS.

Tsuga mertensiana grows mainly at timber line, but far north in the Pacific region it occurs at sea level. Southward in the Pacific region and eastward in the Rockies (Map No. 5) its vertical range is determined by the gradual ascent of favorable climatic and moisture conditions, which for these regions confine the tree to high, cold, moist, mountain slopes and valleys. It thrives in most well-drained soils which are not too dry, but best in loose, coarse, moist ones, at elevations ranging from sea level to about 11,000 feet. The highest elevation attained is in the California Sierras. So far as is now known, its vertical range in the Rocky Mountains is between about 5,500 and 8,000 feet, or occasionally up to 9,000 feet.

The best stands occur on flats, gentle slopes, and at the heads of moist valleys, or in sheltered ravines. It has a decided preference for north exposures, doubtless because it encounters less heat and greater soil moisture there. Although often abundant on exposed high slopes, it is usually stunted in such situations, which are least favorable to the best growth. At high altitudes, mountain hemlock

occurs very commonly in small pure stands and also in mixture with white-bark pine, alpine fir, alpine larch, and Engelmann spruce, while lowland white fir, lodgepole pine, and western white pine are occasional associates at lower elevations. Large pure stands are uncommon, but rather extensive mixed forests are occasionally found containing as much as 85 per cent of this hemlock.

Mountain hemlock is very tolerant of shade, surpassing all of its associates, except western hemlock, in shade endurance. Its dense shade, which in some instances almost excludes light from the ground, usually prevents growth of all seedlings, even of its own, which appear to require more light than is available under the mother trees, but which thrive under lodgepole pine, fir, etc. Seedlings grow more thriftily in moderate shade than in full light. Seedlings and saplings bear long suppression, rarely dying under it, and resume normal growth when top light is admitted. Because of the mountain hemlock's great shade-enduring qualities, the trunks are not readily cleared of branches, even in dense stands. The branches become so large before they die that they usually persist for a long time or leave short stubs, thus forming loose knots in timber.

Tsuga mertensiana is a prolific seeder, some trees beginning to produce cones when about 20 years old. More or less seed is borne annually, but good seed years occur only at intervals of several years. The seed has only a moderate rate of germination, and its vitality is rather transient. With sufficient moisture, seed germinates on both humus and mineral soils, but much more readily on the latter.

LONGEVITY.

The age limit of mountain hemlock is not known at present, but it is believed to be a very long-lived tree, probably attaining an age of from 400 to 500 years. Trees from 18 to 20 inches in diameter are from 180 to 260 years old, while trees only from 5 to 7 inches in diameter growing on high, wind-swept ridges are from 60 to 80 years old.

GENERIC CHARACTERISTICS OF FALSE HEMLOCKS.

The generic name Pseudotsuga, false hemlocks, is applied to a group of trees related to the hemlocks (*Tsuga*), which they resemble in the contracted base of their leaves and in the habit and character of their cones. The resin vesicles peculiar to hemlock seeds, are, however, absent from the seeds of Pseudotsugas. Like the balsam fir trees, the false hemlocks have small resin pockets, or "blisters," in the bark of young trunks and branches. Woodsmen and lumbermen know the trees of this group as "varieties" of "fir" or "spruce," and even as "pines," this being due probably to the superficial resemblance of the wood to that of spruces and pines.

Obviously, however, use of the name pine for these trees is a perversion, for in all respects the pines are totally different trees. Properly, moreover, they should not be called firs, from which they differ greatly in the character of their wood, foliage, and cones.

False hemlocks are evergreen trees with dense, soft, foliage. Their branches, which grow from the trunks in irregular circles, form, with their many side branches, wide fanlike sprays. The rough, thick-barked gradually tapered trunks are tall, straight, and, in the case of one species, very massive. They have broadly pyramidal crowns, which in the case of young trees extend down to the ground.

The flat, bluntish leaves, with contracted bases, are single and spirally arranged on the twigs and branches. They appear often to grow mainly from two opposite sides and from the top of the branches, but by a twist in their stems the lower leaves are bent upward toward each side of the branch. Leaves of a season's growth remain on the tree from about five to eight years. In cross section the leaves show two resin ducts situated near the edge on the underside.

The male and female flowers are each borne singly on different parts of the same tree, the twigs on which flowers are borne being formed the previous year. The female flowers, bristly, scaly bodies which develop into cones with seed, are borne nearly or quite at the ends of twigs, while the male flowers, scaly bodies bearing pollen only, grow from the bases of leaves farther back from the ends of the twigs. Most characteristic of the false hemlocks are their pendulous cones with conspicuous 3-pointed, scalelike bracts, which protrude from among the cone scales (Pl. VI). None of our other native evergreen-leafed conifers that bear cones with persistent cone scales produce exserted bracts. The thin-scaled cones mature in one season, soon afterwards falling from the trees. Two-winged seeds (Pl. VI, *a*) are borne under each cone scale. Their large, light wings permit the wind to distribute them easily. The seed-leaves of Pseudotsuga are flat and vary in number from 6 to 12, being commonly 6.

The trees of this group are of the greatest commercial importance (mainly one species), supplying great quantities of the finest and largest saw timber of any of our native trees, if not of any trees in the world. The slightly resinous, pinelike wood is suitable for all sorts of construction purposes.

Two species of this group are natives of North America. One is distributed more or less from the Rocky Mountain States to the Pacific coast, extending also into adjacent Canadian and Mexican territory, while the other species inhabits the mountains of southern California.

Species of this genus are of ancient origin, the wood of some of them having been found in the Middle Tertiary period of western Canada, while remains of Pseudotsuga taxifolia occur in the Pleistocene of

PSEUDOTSUGA TAXIFOLIA: FOLIAGE AND OPEN CONES.

a, Upper and lower sides of seeds with wings, showing variation in size of wings.

PSEUDOTSUGA TAXIFOLIA: FOLIAGE AND OPEN CONE.

Montana, and those of Pseudotsuga macrocarpa in the Pleistocene of Humboldt County, Cal. [28]

DOUGLAS FIR; DOUGLAS SPRUCE.

Pseudotsuga taxifolia (Poir.) Britton.

COMMON NAME AND EARLY HISTORY.

During the last 30 years Pseudotsuga taxifolia has become very widely known both in this country and elsewhere for its commercially valuable timber. Many confusing common names, such as "red fir," "red spruce," "Douglas spruce," "yellow fir," "Oregon pine," and "Puget Sound pine," have been applied to it in different parts of its extensive range, but it is now generally known as Douglas fir, which commemorates the name of David Douglas, by whom seed of this tree was first sent to England [29] in 1827 from the region of Columbia River, Oreg. Through this seed the tree first became known to science. The tree was, however, first discovered in 1791 by Dr. Archibald Menzies, who found it on Nootka Sound (west coast of Vancouver Island). Dr. Menzies was at that time a surgeon attached to George Vancouver's expedition [30] to the north Pacific coast. Lewis and Clark's [31] account of this tree, published in 1805, was the first printed notice of it to appear. Dr. C. C. Parry's discovery of Douglas fir in the Rockies of Colorado in 1862 is the first instance of its being found east of the Pacific slope.

The botanical history of Douglas fir shows that nearly 30 specific and varietal names have been applied to the tree during the 113 years it has been known to science.[32] The first tenable

[28] Fide Dr. Edward W. Berry. See footnote 4.

[29] Fide J. G. Jack, in Garden and Forest, VI, 14, 1893.

[30] See footnote 19.

[31] History of expedition under command of Lewis and Clark, III, 831 (ed. Coues), 1805.

[32] Douglas fir is said to have been first introduced into cultivation in England from the Pacific region in about 1827. A tree at Dropmore, raised from seed planted at that time, is believed to be the oldest one in England (Frost. in Gard. Chron. 1871, p. 1360).

According to Elwes and Henry (The Trees of Great Britain and Ireland, IV, 824-827, 1909), trials in England of the Rocky Mountain and Pacific slope forms of Douglas fir show that both grow well there, but that trees from the Pacific region grow considerably faster and are, therefore, much more desirable for forest planting there than the Rocky Mountain form.

A number of the largest trees in England planted during the period from about 1830 to 1865 range from about 100 to 128 feet in height and from 4 to 6 feet in diameter.

As nearly as can be determined, Douglas fir was first introduced into cultivation in Europe in 1831. John Booth (Die Douglas Fichte u. e. a. Nadelh., 50, 1877) speaks of the record of a tree 2 years old planted in Germany during that year as the oldest example known there in 1877. This tree was then 48 years old and about 70 feet high, with a diameter of 22 inches. Booth mentions having seen another tree of similar proportions, probably planted at about the same time in the region of Greifswald, Germany, and also one planted near Bremen in 1855, which was 39½ feet high in 1877. It is not known whether or not these trees are the Pacific slope or the Rocky Mountain form.

Extensive tests made by the German Government during the early nineties of both the Pacific slope and the Rocky Mountain forms of Douglas fir show that the former strain grows more rapidly in Germany than the latter, but that the Pacific slope tree is likely to be injured, though not seriously, by early frost, while the Rocky Mountain form is not affected by low temperatures. Because the Pacific slope, or green-leafed, tree produces the better quality of timber, this form appears to be preferred as a forest tree

scientific name applied to Douglas fir is "Abies taxifolia Poiret," published in 1804, on which the present acceptable name, Pseudotsuga taxifolia (Poir.) Britton[33], is based. From 1833 to 1889, the date on which the latter name was established, Douglas fir was known to many botanists as "Abies Douglasii Lindl.," and from 1867 to 1889, as "Pseudotsuga Douglasii, Carrière."

Some 22 different garden varieties of Douglas fir have been named, most of which are distinguished by the size, form of crown, color and shape of leaves, and habit of the branches.[34]

DISTINGUISHING CHARACTERISTICS.

Excepting the great sequoias of California, Douglas fir is the most gigantic tree of our western forests. Under the best conditions for growth, which exist chiefly in the northwest Pacific coast country, it ordinarily reaches 180 or 190 feet in height and from 3½ to 6 feet in diameter. Exceptionally large trees occasionally found are from 200 to 330 feet high and from 8 to 10 feet in diameter.[35] Under less favorable conditions, such as prevail in the range of Douglas fir outside of the humid Pacific coast region (Map No. 6), it commonly attains a height of from 75 to 125 feet and a diameter of from 24 to 40 inches, while in high, exposed situations it is much smaller or greatly stunted, sometimes under 3 feet in height.

The typical crown form of young trees is an open, broad, sharp-pointed pyramid; the lower branches are straight or somewhat

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by a number of German authorities. Others, however, recommend using the Rocky Mountain form because of its greater hardiness.

The first introduction of Douglas fir in eastern United States dates from 1863, when Dr. C. C. Parry is said to have sent seeds of the Rocky Mountain form to the botanic garden of Harvard College. Trees raised from this seed grew thriftily and have proved well adapted to the climate of New England. Later numerous plantings of Douglas fir from its Rocky Mountain range have established the perfect adaptability of the species to our Northeastern States, specimens of it growing fairly well even as far south as the District of Columbia. Douglas fir from the moist climate of its Pacific range does not, as a rule, grow well in our Eastern States.

A number of writers on American trees have maintained that the Pacific slope and the Rocky Mountain forms of this tree are distinct species, this view being based on the common occurrence in the Rockies of blue-leafed trees with the bracts of the cones often reflexed, and of green-leafed trees in the Pacific region with the bracts of the cones usually straight. The decidedly more thrifty growth in Europe and in eastern United States of the Rocky Mountain form, as compared with that of the Pacific slope tree also seemed to indicate specific distinction between these two regional forms. Broadly considered, however, the trees of these regions can not be maintained as distinct species, for the characteristics offered to distinguish them are not dependable, the real difference between them appearing to be wholly of a silvical nature.

[33] Several authors maintain for this tree the name Pseudotsuga mucronata (Raf.) Sudworth, which the writer believes to be lawfully antedated by P. taxifolia (Poir.) Britt. For a full discussion of the basis of this decision, see Bull. 17, Div. For., 23, 1898.

[34] The most distinct and best known of these forms is P. taxifolia pendula (Engelm.) Sudw. and P. taxifolia glauca (Beissn.) Sudw. (Other varieties are listed in Bulletin 17 of the Forest Service, "Check List of the Forest Trees of the United States," 24, 1898, and described by Beissner in his Handbuch der Nadelholz-Kunde, ed. 2, 106, 1909).

[35] In a letter dated Nov. 26, 1912, Mr. Bartle F. Harvey of 265½ Fifth street, Portland, Oreg., called the writer's attention to a Douglas fir tree 14 feet in diameter and 200 feet high, this tree being located about 175 feet from the Tacoma & Eastern Railroad at a point about 2 miles south of the town of Mineral, Pierce County, Wash. The tree is on the tourists' route to Mount Rainier and is visited annually by many people.

drooping and the middle and higher ones trend upward. All of the branches have numerous long, hanging, side branchlets, which are sometimes very long. In dense stands, one-half or two-thirds of the lower branches are shaded out by the time the trees are 10 or 15 inches in diameter. Under these conditions the crowns of middle-aged and old trees lose much of their earlier pyramidal form and become rounded or flattened.

The massive trunks, clear of branches for 80 or 100 feet (in the Pacific region) are straight and taper only slightly. The ashy brown bark of young trees, often with chalky patches, is thin and smooth and but little broken or furrowed, except near the ground, until the trees are from 12 to 14 inches in diameter. Old trees have bark from 5 to 10 inches thick at the base of the trunk, although higher up it is much thinner. Very old trees sometimes have bark from 18 to 24 inches thick. The bark is of a dark brown color outside and a clear red-brown within. It is often very rough, with deep, wide furrows and great ridges, which are connected at intervals by narrower diagonally disposed cross ridges. There is great variation in the character and markings of the bark in dry and humid regions, and also on trees in exposed and protected situations. In exposed, dry situations, such as are common in the southern and middle Rockies, trees have rougher and harder bark than in the moist, dense forest of the Pacific region. Moreover, trees of the high, very dry interior Rocky Mountain slopes, particularly young trees, may have soft, corklike,[36] gray-brown bark. This may well be a result of the excessively dry atmosphere, for one or two balsam firs of that region have similar bark. In other characteristics, however, these trees do not differ from those with the ordinary bark.

Mature foliage is usually a deep yellow-green. In the drier parts of its range, particularly in the Rocky Mountain region, Douglas fir sometimes has blue-grass[37] foliage of varying shades. These blue shades are especially pronounced during the early maturity of the leaves. Each season's growth of leaves remains on the tree about eight years, soon after which it is shed at irregular intervals. The leaves (Pl. VI) are flat, slightly grooved above and commonly blunt, or very occasionally pointed.

The cones (Pls. VI, VII) ripen early in August, and by September they are of cinnamon or reddish brown color. Their scales soon begin to open and shed their seed, the cones dropping from the

[36] The variety "Pseudotsuga taxifolia suberosa Engelmann" is a form of Douglas fir with bark of this character.

[37] About 20 or more different garden varieties and other forms of this tree now distinguished in cultivation are based on color of the foliage and similar individual characteristics.

trees a few weeks later. One of the simplest means of identifying this tree is by the 3-pointed, tridentlike, thin bracts[38] protruding from among the cone scales. Cones vary in length from 1½ to 4½ inches, but commonly from about 2½ to 3 inches. The seeds (Pl. VI, *a*) are dull russet-brown, with areas of white. Seed-leaves, about three-fourths of an inch long, vary in number from 6 to 7 (Pl. VIII).

The wood of Douglas fir varies greatly in quality and in the thickness of annual rings, which may be very wide, medium wide, or narrow. Wide-ringed wood is usually a distinctly reddish brown, this being the "red fir" of lumbermen. Narrow-ringed wood is usually a clear yellowish brown, the "yellow fir" and "Oregon pine" of lumbermen. The botanical characteristics of trees furnishing these dissimilar qualities of wood are the same, and there is no foundation for the popular belief that the woods come from two different "varieties" or "species" of trees; indeed, the two grades of wood may sometimes be obtained from the same tree, the wide-ringed wood being in the center of the trunk and the narrow-ringed wood in the outside portion. For the first 50 to 100 years or more diameter growth is rapid, giving wide-ringed wood ("red fir"), while the later stages of growth are, as a rule, slower and give narrow-ringed wood ("yellow fir"). The invariable difference in color between these two grades of wood is often attributed to the character of the soil, but this explanation ignores the fact that both grades may come from the same tree. Grades intermediate between these are also common, especially in trees grown outside of the humid northwestern range, from which the bulk of "red" and "yellow" timber is obtained. Both grades are exceedingly important commercially, but the narrow-ringed, yellow wood is the more valuable, being extensively used at the present time for the finest sorts of finishing lumber, for which it competes with high-class pine. Douglas fir wood compares closely in weight and texture with western yellow pine, a cubic foot of thoroughly seasoned fir wood weighing about 32 pounds. The yellow-wooded form is much more durable when exposed to the weather or earth than the red-wooded form, the lasting qualities of both grades being rather remarkable when they are used for piling.[39]

[38] As a rule, the bracts of the Rocky Mountain form of Douglas fir are strongly reflexed (Pl. VII), those of the Pacific slope tree remaining more or less straight (Pl. VI). The latter peculiarity is, however, confined wholly to the more western form of this tree.

[39] In a letter to the writer, dated February 12, 1909, Mr. F. H. Conant says that during lumber operations in (sec. 15, T. 21 N., R. 8 E.) west Washington, two sound logs were cut from a large fallen Douglas fir on the top section of which (then decayed) a 240-year-old western hemlock (cut at that time) had grown. The inference that two sound logs were obtained from the fallen Douglas fir after all those years seems scarcely credible.

PSEUDOTSUGA TAXIFOLIA: SEEDLINGS.

a, 1 year old; *b*, 2 years old.

OCCURRENCE AND HABITS.

In the Rocky Mountain region Douglas fir occurs generally at elevations between about 4,000 and 11,000 feet, the lower elevations being at the North, while in the central and southern Rockies the altitudes attained are from about 6,000 to 11,000 feet (Map No. 6). In the northern Pacific coast country it occurs at sea level. It grows best and in greatest abundance where precipitation and relative humidity of the air are greatest. Except at high elevations and at the northern limit of range, Douglas fir prefers northern to southern exposures, and sheltered slopes, canyons, benches, etc., to exposed situations. At the North, and at high elevations, warmer southern exposures are preferred, for heat, not moisture, then becomes the controlling factor in its growth. The lower limit of vertical range in drier regions is determined by lack of moisture, and the upper limit of distribution is marked chiefly by lack of heat. Douglas fir occurs at higher levels on the east sides of mountains than on the west sides, higher elevations also being reached on southern slopes than on northern exposures. But it is more abundant on western slopes than on eastern slopes, and likewise more frequent on northern than on southern exposures—except at the far North, where heat is the essential factor.

Douglas fir is adapted to a great variety of soils, including nearly all with sufficient moisture, from the border of brackish seacoast water to soils in which, among other trees, only the drought-enduring western yellow pine grows. It prefers fresh, well-drained, porous, deep, loamy soils, avoiding saturated, poorly drained, heavy soils. Good soil and abundant atmospheric and soil moisture are necessary for the best growth, but with abundant moisture, quantity and quality of soil are less important, and vice versa. Douglas fir grows faster and larger on poor gravels and sand in the humid Puget Sound country than on the best soils of the Rocky Mountains, where it is subject to dry air and deficient precipitation; likewise, it is not so large on the best soils of the drier California mountains, even though the climate is mild and heat and sunshine are sufficiently abundant for other tree growth.

Douglas fir forms large pure forests and often nearly pure stands, but chiefly it is associated with a number of other species. In the northern Rocky Mountain region it grows with western white pine, western yellow pine, lodgepole pine, western red cedar, lowland white fir, western hemlock, Engelmann spruce, alpine fir, and western larch. Here the climatic and soil conditions are similar in great measure to those of the northern Pacific slope country, and account for the presence of so many typically west-slope trees. In the middle Rockies, where the climate and soils are dry, Douglas

fir is associated more often with lodgepole pine and Englemann spruce, while western yellow pine grows with it at the lower elevations and alpine fir at its upper limits of range. The southern Rockies and adjacent dry interior mountains, into which Douglas fir extends, are characterized by climatic conditions differing greatly from those of the middle and northern parts of this chain of mountains, so that here Douglas fir is variously associated with limber pine, Mexican white pine, bristle-cone pine, Engelmann spruce, white fir, cork fir, Gambel oak, and aspen.

Douglas fir is moderately tolerant of shade in its earlier growth, becoming less so with age. Tolerance, however, varies with the locality and region, being greatest under the conditions productive of the best growth. The tree endures more shade than western yellow pine, sugar pine, western white pine, and lodgepole pine, but less than western hemlock, western red cedar, white and alpine firs, incense cedar, and Engelmann, blue, and Sitka spruces. Partial shade and shelter are very necessary in the early life of Douglas fir wherever the conditions for growth are least favorable. At the North, where moisture is abundant, it thrives in the open from early youth, while in drier interior regions it prefers the shade of weeds, brush, etc. Dense pure or mixed stands in the Northwest have clean trunks for about two-thirds of the length, while trees of open forests and those in the Rocky Mountains are clean-trunked for only about one-third their length, or, in scattered stands, carry branches almost to the ground. The trunks clean themselves of side branches slowly even in dense stands, which indicates considerable tolerance of side shade; on the other hand, young trees in dense stands grow rapidly in height, showing their need of overhead light.

Douglas fir is generally a prolific seeder, producing seed nearly every year, with specially good local seed years at intervals of three or four years. The seed is matured at about the same time throughout the tree's range. Throughout the range of Douglas fir its seed formation is nearly as abundant and its power of reproduction nearly as great as in the case of western yellow pine. At best the seed has a moderately high rate of germination and persistent vitality. Not infrequently, however, the seed has a rather low percentage of germination, which may be due in some measure to the fact that a large number of seeds are destroyed by insects. Many are also eaten by birds and rodents. Germination and early development of seedlings are best on warm, moist, pure mineral soil, or in one mixed with humus. Reproduction is rare on thick duff or vegetable matter, but abundant in humid regions after this layer has been burned off, or thoroughly broken up by logging operations. Unburned, logged areas in this moist region are more commonly

restocked by western hemlock and red cedar. In the drier more southern Rocky Mountain range of Douglas fir, burned-over ground is usually unfavorable to reproduction of this species, lodgepole pine, aspen, and other trees usually restocking such areas. Under the most favorable conditions, reproduction of Douglas fir is extremely dense, an acre sometimes carrying over 30,000 trees about 3 feet high and 11 years old, while a stand of 26-year-old trees may average 1,068 per acre, 45 feet high and 3½ inches in diameter.

LONGEVITY.

Douglas fir is a very long-lived tree. Specimens from 3 to 4 feet in diameter are from 150 to 200 years old, while those from 4 to 8 feet in diameter are from 200 to 375 years old. One tree 9 feet through showed an age of 435 years. The ages of rare trees larger than this are probably from 400 to 500 years.[40]

GENERIC CHARACTERISTICS OF INCENSE CEDARS.

Trees of the group Libocedrus are characterized by their conical trunks, thick bark, and the very strong but pleasant odor of their light, soft, straight-grained, durable wood. The branchlets are arranged in one plane, forming flat, fanlike sprays. The twigs of adult trees are clothed with evergreen, scalelike, pointed leaves, which overlap each other closely (Pl. IX *a*, *b*). On the short side branchlets the leaves are much flattened, but on the larger main stems they are rounded. The leaves of each season's growth remain on the tree for about 4 or 5 years. In the case of seedlings the leaves are needlelike, flat, sharp-pointed, and spreading (Pl. X, *b*). As the plants grow older this juvenile form of leaf is succeeded by shorter and less and less spreading ones, until finally the scalelike adult form of foliage is assumed. All of the leaves are arranged in pairs, each pair being placed on the branch at right angles to the preceding pair. The adult leaves also have characteristically long bases, which extend downward, completely covering the branch, a habit on which the technical specific name, decurrens, of our native incense cedar is based. The seed-leaves (first foliar organs produced) are needlelike and flat and usually two in number, or occasionally three (Pl. X, *a*).

Both the male and female flowers are small, inconspicuous, oval or elongated bodies borne at the ends of branchlets produced the previous year, the male flowers being of a yellowish green and the female of a greenish color. They are both formed during the autumn, but they open late during the succeeding winter or in early spring. Flowers of the different sexes are sometimes borne on the same tree,

[40] Mr. F. H. Conant (see footnote 39) states (l. c.) that in secs 9 and 15, T. 21 N., R. 8 E., in west Washington, he counted the annual rings of growth of several trees which proved to be 600 and 700 years old.

even on different twigs of the same branch, but as a rule they are borne on different trees.

The small cones (Pl. IX, *a*) which mature in one season, are composed of 3 pairs of scales (practically of only 2 pairs). The first or basal pair is at the base of the cone; a second pair, the largest, forms most of the cone's body and incloses 1 or 2 winged seeds (Pl. IX, *c*) on each of its scales; the third pair is joined into a central flat, thick, woody wall, upon each face of which one of the preceding seed-bearing scales clasps. The seeds (Pl. IX, *c*) are ripe in early autumn and are shed soon afterwards, their large wings aiding greatly in wide dissemination by the wind. After shedding their seeds some of the cones remain on the trees at least until the succeeding summer.

All of the species of this group, eight in number, are rather large, important forest trees, which produce durable commercially valuable wood. Nearly all of them are long-lived trees. One species only inhabits the United States, this being confined chiefly to our Pacific region. Seven other species are natives of western South America, New Zealand, New Caledonia, and China. The group is further interesting from the fact that in geologic times species related to those now living existed in the upper Cretaceous, Oligocene, and Miocene periods of Europe, as well as farther north in Spitzbergen and Greenland. A well marked species of Libocedrus has been found in the Miocene Lake bed at Florissant, Colo.[41]

INCENSE CEDAR.

Libocedrus decurrens Torrey.

COMMON NAME AND EARLY HISTORY.

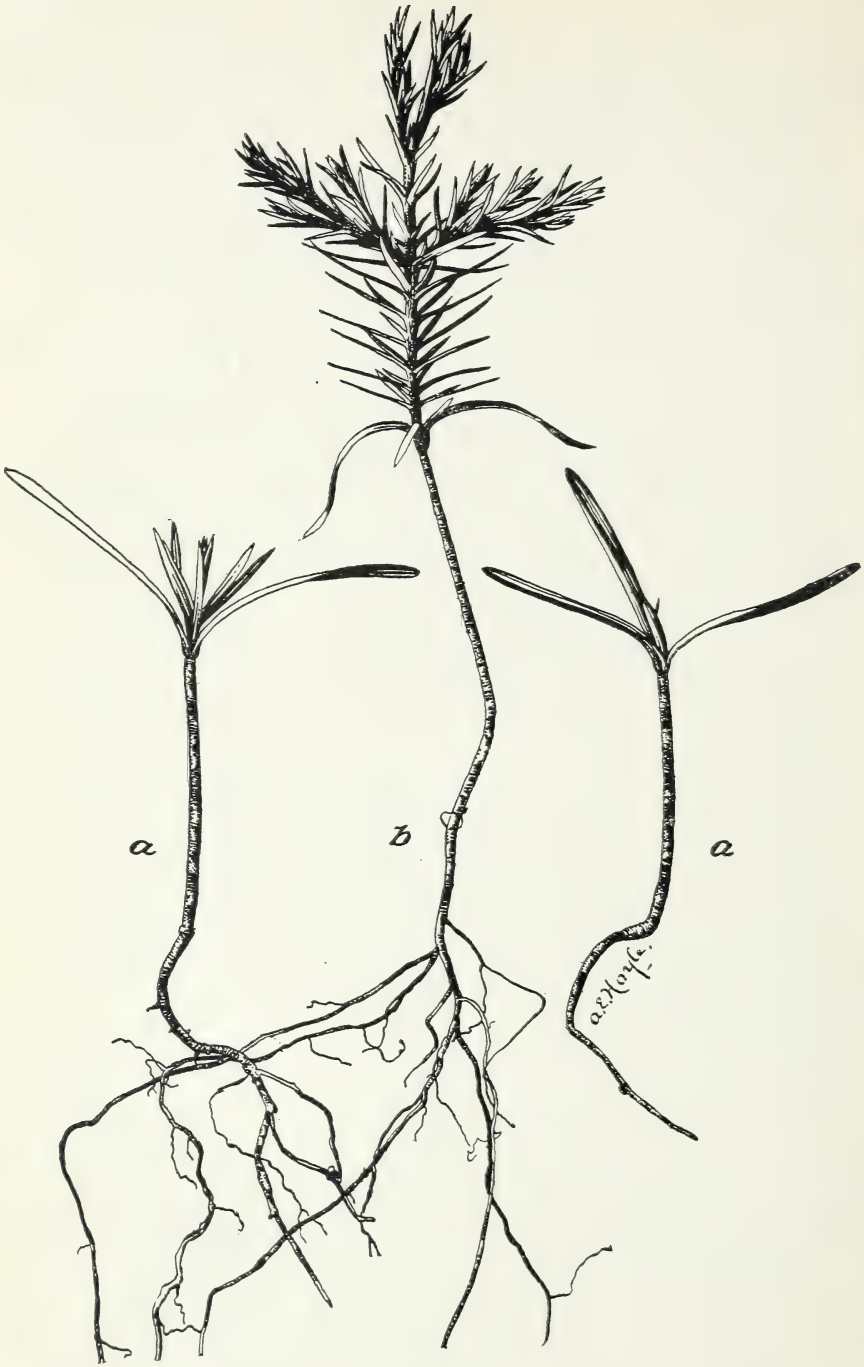
Libocedrus decurrens is variously known throughout its range by such common names as incense cedar, post cedar, bastard cedar, and white cedar, none of which is very generally adopted. The name incense cedar is as widely used as any, and would appear to be most preferable because it refers to the incenselike odor of the wood, which is a distinctive feature. The other common names applied to it are undesirable because they are either meaningless or conflict with previously established common names of some other native trees.

Incense cedar is only sparingly represented in the western edge of the Rocky Mountain region (Map No. 7), where it was first discovered in 1871 at a point in the Washoe Mountains above Carson City, Nev. Later (1911) it was again found very near the Nevada line in Alpine County, Cal. Its main range lies in the Pacific slope country, where Capt. John C. Frémont found it in 1846 on the headwaters of the Sacramento River. The first technical name (*Libo-*

[41] Fide Dr. Edward W. Berry, see footnote 4.

LIBOCEDRUS DECURRENS: FOLIAGE AND CONES.

a, Ripe, partly opened cones; *b*, branch with male flowers; *c*, seeds and their wings.



LIBOCEDRUS DECURRENS: SEEDLINGS.

a, 1 month old: *b*, 4 months old.

cedrus decurrens Torr.), applied to this tree was published with its accompanying description, in 1854, and since that time the tree has been known to botanists practically only by this name. The botanical history of Libocedrus decurrens contains little or no confusion with other similar trees, and but three technical names, now synonyms, have been applied to it during the 62 years it has been known to science.[42]

DISTINGUISHING CHARACTERISTICS.

The striking characteristics of old incense cedar trees are their rapidly tapering trunks with widely buttressed bases and their thick, cinnamon-brown, deeply furrowed, and ridged bark. The bark of such trees is from 2 to 3 inches thick, or more, at the base of the trunks, while higher up it is scarcely more than an inch thick. Young trees have thin, smooth, slightly scaly bark of a clear, cinnamon-red color. Mature trees are ordinarily from 80 to 100 feet in height, and from 30 to 50 inches in diameter; exceptionally large trees are from 125 to 160 [43] feet in height and from 6 to 8 feet in diameter. The clear length of stem among large trees varies from 40 to 70 feet. The largest size is attained in the Pacific region, trees within the limited Rocky Mountain range rarely exceeding 70 feet in height and 30 inches in diameter.

The crowns of large trees are very open and irregular, consisting of a few short, scattered branches on the upper third of the stem, and sometimes several large, leaderlike top branches, all with dense tufts of light yellow-green foliage. Young trees, up to about 12 inches in diameter, that have grown in full light, carry a pointed, narrow, open, columnar crown, which usually extends down to the ground. At the bottom of the crown the branches are slender and curve down and up at their ends; higher up on the trunk they grad-

[42] Libocedrus decurrens appears to be very generally planted for ornament in the British Isles, and in west central and southern Europe, where the tree seems to be well adapted for growth. It is said to have been first introduced into cultivation in Scotland in 1853. Elwes and Henry (Trees of Great Britain and Ireland, III, 492, 1908) mention a tree planted there in 1863, which, in 1905, measured 53 feet in height and about 21 inches in diameter. Another tree mentioned, probably the first one grown in England, was planted "about 1850," and in 1907 measured 53 feet in height and about 32 inches in diameter. The largest tree found by these authors in England was planted in 1857, and in 1904 was 64 feet high and 30 inches in diameter. Much larger trees were found in northern Italy, two specimens mentioned by Elwes and Henry (l. c.) each being 90 feet high and 37 and 39 inches in diameter.

Just when Libocedrus decurrens was first cultivated in eastern United States is unknown. It grows well in the middle Atlantic States, but is not hardy north of southern New York. Probably the earliest planting of this species in the East was by Mr. William Saunders, who set several trees in the grounds of the Agricultural Department, at Washington D. C., about 1867, Mr. Saunders then being superintendent of the department grounds. One of these trees, still standing, is now about 30 feet high and 14 inches in diameter.

[43] Probably the largest incense cedars now known are two trees recently reported by the district forester of district 5. The larger in diameter of these trees, located near Morgan Springs, Tehama County, Cal. (in the Lassen National Forest), is 120 feet in height and 8 feet in diameter, and is estimated to contain 9,700 board feet. The taller is located in the Shasta National Forest (California) and measures 161 feet in height and 83 inches in diameter. Since these two records were obtained, Mr. J. Alfred Mitchell reports trees ranging from 162 to 183 feet in height, and one tree, recently cut, that was 186 feet high. (Bul. 604, U. S. Department of Agriculture, pp. 13, 14, 1918.)

ually swing upward more and more toward the narrow-pointed top. Short, flat, drooping sprays of foliage terminate the branches. A notable feature of the branches is that they shed numerous short side twigs, which die in about their second or third year as the main divisions of the branch enlarge. (This is true also of other cedars, particularly Thujas.) The form and habit of the adult and juvenile leaves and of the cones have already been defined in detail under the "Generic Characteristics of Incense Cedars."

The flowers of incense cedar open in midwinter or very early spring (Pl. IX, *b*). Both the male and female flowers are each borne on the ends of separate year-old twigs, either of the same tree and branch or of different trees. The cones (Pl. IX, *a*) are ripe by the middle or latter part of August and usually begin to shed their yellowish brown, large-winged seeds (Pl. IX, *c*) late in September, most of the seed falling by the end of October. When the cones are dry and fully open they are of a reddish brown color and the two large outer cone scales are spread wide apart. Most of the cones fall from the trees during the succeeding winter, but some always adhere to the branches until the following spring or summer. The seeds contain glands with clear red, pungently odorous resin. Seed-leaves, two in number, or occasionally three, are usually blunt or only slightly pointed, and about $1\frac{1}{4}$ inches in length by almost one-eighth of an inch in width (Pl. X, *a*). The succeeding primary leaves are sharp-pointed and stand out from the stem (Pl. X, *b*). Within one or two seasons' growth the primary leaves are followed by the adult form of foliage.

The wood of incense cedar is sometimes rather wide-ringed, but usually it is narrow-ringed and very straight-grained, the heartwood varying in color from a pale or dull yellow-brown to a light brown tinged with red, the sapwood being a creamy white. It is soft, light, a cubic foot of seasoned wood weighing about 25 pounds, and very durable under all kinds of exposure. Its great durability renders it extremely valuable for use in the water or in the ground, where it may remain sound for from 25 to 30 years or more. Large trunks and, to a much less extent, small or medium-sized ones, are often riddled by a "dry-rot fungus," as if by the galleries of a wood-boring insect. This injury, however, is now known to result from the attack of a fungus called *Polyporus amarus*. They necessarily weaken the trunk logs and render much of the wood useless for lumber, but the durability of unattacked portions of the wood is in no way impaired. Trunks not excessively perforated are frequently used for telephone poles, especially in the Pacific slope range of the tree, where, with the exception of redwood and bigtree timber, it is the only lasting wood obtainable for this purpose. In general appearance and texture the wood of incense cedar is quite similar to that of the western red

cedar (*Thuja plicata*). It is locally used for several of the same purposes for which the latter is employed, such as fence posts, telephone poles, light-traffic railway ties, shingles and shakes, sash and doors, and "edge-grain" flooring, and some other interior finishing material. Its soft, brittle texture and the ease with which it "chips" has also recently brought this wood into use for cheap grades of lead pencils.

OCCURRENCE AND HABITS.

Libocedrus decurrens occurs more commonly, as a rule, on western than on eastern mountain slopes. It ascends somewhat higher on the western slopes, chiefly because of greater moisture on such exposures. The vertical range of incense cedar in the Pacific slope region varies from about 3,500 to 7,500 feet, in exceptional instances descending as low as 1,500 feet and ascending to about 9,000 feet elevation. In its dry range within the Rocky Mountain region it is confined mainly to canyons, gulches, and cool north slopes, at an altitude of about 7,000 feet (Map No. 7). Incense cedar is adapted to a variety of soils, but grows best in cool, moist, gravelly, porous soils. It occurs also in rather dry soils (warm exposures), yet probably only because it can endure them. With deficient soil moisture, fairly deep, porous soils are essential, while with sufficient moisture the quantity and quality of soil is less important.

In the Pacific slope region incense cedar occurs variously in mixture (but more or less subordinate), scattered singly, or in groups and patches, mainly with western yellow pine, Jeffrey pine, Douglas fir, white fir, red fir, California black oak, and sometimes with bigtree. Under the best conditions for growth in this region it occasionally forms from 25 to 50 per cent of the stand, particularly within the range of western yellow pine and sugar pine. But in its limited range in the Rocky Mountain region incense cedar forms only a very small percentage of the stand and occurs mostly with western yellow pine.

Incense cedar is moderately tolerant, enduring more shade than western yellow pine, western white pine, and Douglas fir, and is usually intermediate or subordinate in mature stands because of its slower growth and greater tolerance. It is adapted both to moderate shade and full light, but requires less light in youth than in later life and tolerates most shade under conditions favorable to good growth. Its tolerance varies, however, not only with age, but also with atmospheric and soil moisture, character of soil, and climate. Rapidity of growth and size attained in later life are checked ordinarily n proportion to the intensity of shade to be endured.

Incense cedar is a prolific seeder every two or three years under favorable conditions of growth, some seed, however, being borne locally about every year. Thrifty, mature trees standing in full

sunlight produce the largest amount of seed. Even small scrubby trees in open places usually bear relatively large crops of seed. The seed has a comparatively low rate of germination (15 to 45 per cent) and fairly persistent vitality. Because of their large light wings the seeds are widely distributed by wind. Germination of the seed and growth of seedlings are best in moist vegetable mold, but excellent also on moist mineral soil. Partial shade is favorable to early growth of seedlings because soil moisture is conserved under such conditions. Lack of sufficient soil moisture during the critical early period of growth often results in the death of large numbers of seedlings. Good reproduction occurs under the partial shade of old trees, but it is particularly abundant in open places in thin stands, where dense thickets of young incense cedar frequently exclude other seedling trees. In cool moist places, however, white fir may enter such thickets and later become predominant. Incense cedar is often the first conifer to establish itself at the lower edge of its vertical range in chaparral and oak growth, proving its great adaptation to different degrees of light, moisture, and character of soil, as well as its general hardiness during seedling stages of growth.

LONGEVITY.

Much is yet to be learned regarding the age limits of this tree. So far as is now known, it is long-lived, but the ages of very large trunks have not been determined, chiefly because the centers of old trees are often so completely destroyed by fungi as to prevent counting the earlier growth rings. Narrow-ringed trees from 24 to 36 inches in diameter are from 360 to 546 years old. One wide-ringed tree examined by the author was 42 inches in diameter and only 115 years old, showing exceptionally rapid growth. The largest trees are probably from 600 to 800 years old, or possibly one or two hundred years older.

GENERIC CHARACTERISTICS OF ARBORVITÆS.

The trees belonging to the group which is technically called Thuja are commonly known as "cedars" or arborvitæ.[44] They are medium to very large-sized evergreen trees. The adult form of foliage consists of minute, overlapping, scalelike leaves, arranged as in Libocedrus, and conspicuously flattened on the short side branchlets, which are arranged in one plane, thus forming flat sprays (Pl. XI, XII). The back of the leaf is marked with a tiny gland or small pitlike depression. Seedling leaves are narrowly lance-shaped and sharp-pointed, and spread widely from the stem (Pl. XI, *b*).

[44] Nurserymen and many writers treating of coniferous trees from the standpoint of horticulture appear to favor calling species of the genus Thuja arborvitæs. A number of botanical writers also favor this. Lumbermen, woodsmen, and others concerned with the use of the wood of these trees, however, uniformly or with few exceptions, designate them as cedars.

The male and female flowers are borne on the same tree, but each sort is usually on different twigs. They are minute, inconspicuous, elongated bodies, especially the female flowers, borne at the ends of the twigs and opening, as a rule, in early spring.

The small solitary cones (Pl. XI) mature in one season, shedding their minute, very narrowly winged seeds in early autumn (Pl. XI, *a*). The cones, strongly bent back upon the branchlets, are composed of about 8 thin scales, which are arranged in pairs, each pair set at right angles with the preceding one, just as in the arrangement of the leaves. The two or three middle pairs of scales, which are larger than the others, each bear two seeds. The thin, gauzy seed wings, attached on two sides of the seed, and always of a lighter color than the body of the seeds, render the seeds very buoyant, so that they are carried by the wind for long distances from the parent trees. Minute resin cells in the seed coats give the seed a strong aromatic or cedar-like odor similar to that of the wood.

The wood of the Thujas is very light, soft, and has a characteristic aromatic or cedarlike odor. It is exceedingly valuable for timber, particularly on account of its durability under all kinds of exposure, and especially in earth and water.

Two species of this group are indigenous to the United States and Canada. One, a small or medium-sized tree, inhabits our northeastern States and adjacent Canadian Provinces; the other, a very large tree, grows in northwestern United States and northward in the Pacific coast region to Alaska.

Trees of this genus are of ancient origin, representatives of them having existed throughout the northern hemisphere during the upper Cretaceous and Eocene periods of the earth's history. Remains of them are found abundantly in the Baltic amber (Oligocene) and in the Miocene of Europe and North America. Geologic remains of our northeastern white cedar, Thuja occidentalis, occur in the Pleistocene formation of Canada, Ohio, and Virginia.[45]

WESTERN RED CEDAR; "RED CEDAR."

Thuja plicata D. Don.

COMMON NAME AND EARLY HISTORY.

Like the incense cedar, the western red cedar occurs chiefly in the Pacific coast region, its range in the Rocky Mountain region being confined to Montana and Idaho and adjacent Canadian territory (Map No. 8).

Lumbermen and other woodsmen of the Northwest call it "red cedar," or simply "cedar," while for the most part nurserymen know

[45] Fide Dr. Edward W. Barry, paleontologist, Johns Hopkins University, Baltimore, Md.

it as "giant arborvitæ."[46] Northwestern woodsmen also call it "canoe cedar," because the Indians use the easily worked big trunks for canoes. The name "red cedar" is fairly applicable to the dull, slightly reddish brown wood, but use of the name for Thuja plicata would at once confuse this species with the eastern red cedar (*Juniperus virginiana*), which has really red wood, and was discovered nearly a century before the western cedar became known to science. It seems best, however, to adopt the common name western red cedar for Thuja plicata in order to avoid confusion that would result from applying the name "red cedar" to two different trees.

Western red cedar was first discovered by Luis Née on Nootka Sound some time during the years 1789 to 1794,[47] in which Née served as one of the botanists who accompanied the Spanish explorer Malaspina in his voyage around the world. Two years later (1796), Archibald Manzies found it on Vancouver Island while he was serving as surgeon to Capt. Vancouver on the latter's voyage to the Northwest coast. It was probably later introduced from this region into European gardens, where it appears to have been cultivated long before it became known to botanists.

The first technical name applied to the western red cedar is "Thuya plicata" of D. Don, who properly published it in 1811, although in 1807 James Donn published the bare name Thuya plicata (without a description), and attached it to Née's original specimen of this cedar. Thuja[48] plicata is, therefore, the technical name by which western red cedar should now be known. Western red cedar was, however, long and exclusively known to botanists as "Thuya gigantea Nuttall," a name which was established in 1834, 23 years after "Thuya plicata" was published. The latter name was not restored to use at an earlier date chiefly because the plants cultivated as "Thuya plicata" in European gardens were believed to represent more nearly forms of our northeastern white cedar (*T. occidentalis*) than of the western red cedar.

Just when Thuja plicata was first discovered in the Rocky Mountain region is unknown. Probably, however, it was in about 1832 or 1833, and doubtless Nathaniel Jarvis Wyeth was the first American collector to secure botanical specimens of the tree in that region. Thomas Nuttall,[49] who described Wyeth's specimens, informs us that Wyeth's collection of plants, including western red cedar, was obtained "chiefly in the valleys of the Rocky Mountains or Northern

[46] A common name coined from the technical name Thuja gigantea, formerly applied to this species but now replaced by T. plicata, the oldest name for the tree.

[47] M. T. Masters, in Gard. Chron. XXI, 3d Series, 101, 214, 1897, the specimen collected by Née being preserved in the Natural History Museum at South Kensington, England.

[48] Linnæus' later spelling, Thuja (Hort. Cliff. and Spec. Plantarum, 1737, 1753), is here maintained in place of the first spelling, Thuya.

[49] Journal of the Academy of Natural Sciences, VII, part 1, 5, 1834.

Andes, toward the sources of the Columbia River." A little further on in his paper (l. c.) Nuttall says "This collection was made wholly on the returning route of Mr. Wyeth from the falls of the Columbia to the first navigable waters of the Missouri."[50]

About a dozen named horticultural varieties of western red cedar have originated in European gardens, and all are distinguished by the color of the foliage, habit of the branches, and form of the crown. Five of these are fairly distinct as garden forms in the shape of the crown, habit of the branches, and coloration of the foliage. Thuja plicata gracillima (Beissner) Sudw. is distinguished by its small delicate branches. When grown in rich, moist soil this form produces the stouter branches, showing a tendency to revert to the normal type. T. plicata compacta (Carr.) Beissner has a compact fastigiate crown of thin delicate branches. T. plicata penduliformis Sudw. has long, slender, drooping branches and twigs, similar in general appearance to the weeping willow. T. plicata atrovirens (Gord.) Sudw. is distinguished by exceptionally dark-green brilliant foliage. T. plicata variegata Carr. has golden-yellow mottled foliage, while a similar form, T. plicata albo-maculata (Hort. ex Beissner), has white-mottled foliage.

DISTINGUISHING CHARACTERISTICS.

Perhaps the most prominent characteristic of western red cedar is its decidedly conical trunk form, which, in the case of very old trees, includes an enormously developed base ("swell-butted"), the latter being conspicuously infolded or fluted for from 10 to 20 feet above the ground. The thicker layers of wood formed on these ridges appear to be made at the expense of the thinner layers of wood in the intervening hollows, the different rates of growth thus resulting in a fluted trunk. The fluted appearance is less pronounced in the case of small trees. Height and diameter growth varies greatly from the

[50] According to Elwes and Henry (l. c.), W. Lobb introduced Thuja plicata into cultivation in England in 1853, the trees raised in Veitch's nursery at Exeter having been distributed under the name "Thuja lobbi." These authors state that the largest trees now growing in England were raised from seed planted in about 1860, and were, in 1906, approximately 95 feet in height and 3¼ feet in diameter. Many trees in various parts of Great Britain now over 60 or 70 feet high were grown from seed within 50 years. The above authors state that Thuja plicata flourishes also in Wales, Scotland, and Ireland, where there are a number of trees from 60 to 70 feet high and from 2 to nearly 3 feet in diameter. The excellent timber and ornamental form of this tree and its rapid growth have made it a favorite in Great Britain, where small forest plantations of it already have been set out.

As nearly as can be ascertained, Thuja plicata was first grown in Germany in about 1878. Few of the trees raised, however, survived serious injury from late frosts and the fungous disease known as Pestalozzia funerea, this disease killing many of the trees after they had reached an age of 10 years. In the early nineties the German Government imported considerable quantities of the seed of this species to test further the tree's value for forest planting in Germany. The tree was also extensively tested in Austria. Little is known now of the exact results of all of these trials, except that late frosts and the above-mentioned fungous disease greatly hindered the growth of the trees.

Thuja plicata has been sparingly planted for ornament in our northern and middle Atlantic States. Prof. C. S. Sargent (Silva, X, 130, 1896) says it endures the winters of eastern Massachusetts. Seedlings raised from seed sown in the spring of 1916 at Letchworth Park Forest and Arboretum, Wyoming County, N. Y., have survived the winter of that year and probably will prove hardy in that locality, although at least several years' trial are necessary to establish this as a fact.

largest development, which is attained chiefly in the Pacific region, to medium or small-sized trees produced in the Rocky Mountain region; while at high elevations in both regions trees are often only a few feet high. Large trees are from 150 to 175 feet in height, or very exceptionally from 190 to 200 feet, with diameters of from 5 to 8 feet, or, in the case of very old trees, sometimes from 10 to 18 feet through.[51] Small and medium-sized trees range from 60 to 120 feet in height and from 2 to 4 feet in diameter. The enormous girth of the largest trees is at the base; their diameter decreases so rapidly that at 20 feet from the ground they may be no more than 9 or 10 feet in diameter. In such trees, from 60 to 100 feet of clear trunk is common, while the clear trunk of smaller trees is from 10 to 50 feet. It is only in densely crowded stands that trees have long, clear trunks, and even then they often have scattered branches below the main crown. The boles of young trees are fairly straight, but large trees are frequently bowed or slightly bent and are rarely perfectly cylindrical.

Young trees have narrow, open, conical crowns reaching almost to the ground and tapering to a sharp top, the slender whiplike leader usually nodding in a graceful curve. Old trees in dense stands have only a short, blunt, or round-topped conical head. A notable characteristic of western red cedar is the frequent production of two leaders, which combine in forming a dense crown. Except when growing in very dense stands, trees retain practically all their branches until they are 18 or 20 inches in diameter and from 50 to 80 feet high, while trees growing in the open become much larger before they lose their lower branches. On young trees the slender branches all curve upward, but later as the limbs become very long, the lower ones droop and those higher swing down in a long, graceful curve, with an upward sweep at the ends. The flat, lacelike, yellow-green side sprays hang from the branches like lines of fringe.

The bark of western red cedar is thin, even that of old trunks being only from five-eights to seven-eights of an inch thick. Because of its thin bark this tree rarely escapes being fatally injured by fire. Freshly broken bark is of a clear, reddish, cinnamon-brown color, but externally it is often weathered to various shades of grayish brown, depending upon exposure to the light. The bark is distinctly but shallowly seamed, the narrow ridges being flat on young trees and rounded on old trunks. The main ridges run irregularly but continuously, with rare breaks, and are connected at short inter-

[51] Under date of February 12, 1909, a letter from Mr. F. H. Conant, of Auburn, Wash., gives the diameter of a western red cedar cut in sec. 8, T. 23 N., R. 9 E., west slope of the Cascade Mountains, King County, Wash., as 18 feet 4 inches at a point 12 feet above the ground. The height of this tree could not be accurately measured because the top was dead and had been broken off. Mr. Conant mentions another tree about the same size standing near the tree cut. A decay at the center of the tree cut was 6 feet in diameter. Allowing sufficient time for the tree to have attained 6 feet in diameter, the writer found that by counting the annual layers of growth in the sound wood this cedar must have been approximately 2,265 years old when it was cut.

THUJA PLICATA: FOLIAGE AND CLUSTER OF OPEN CONES.

a, Seeds and their wings; *b*, seedling 2 months old.

THUJA PLICATA: FOLIAGE AND OPEN CONE.

vals by thinner diagonal ridges and fibers. In texture and appearance the bark is more or less stringy and fibrous, so that in the case of young trees it may be separable into long, thin strips, while in the case of old trees the bark is separable only into shorter scales. The inner bark is very tough and strong, particularly that of young trees, from which Indians peel strips of bark 20 or 30 feet long for basket making.

The small scalelike leaves (Pls. XI, XII), the arrangement of which is described under the "Generic Characteristics of Arborvitæs," remain on the trees about 3 years. Leaves of vigorous leading shoots usually have a tiny gland on the back side, while the leaves of the more slowly grown lateral twigs are marked on the back by a small pitlike depression. As the main stems of a branch grow, their short, flat, side branchlets die and fall during their second year, as is the case also with similar sprays of Libocedrus. The leathery-brown cones (Pl. XI), which mature by the end of August, have about 6 seed-bearing scales, each of these producing from 2 to 3 seeds. After shedding their light double-winged seeds (Pl. XI, *a*) the cones remain on the trees until the following spring or summer. The seed-leaves, 2 in number, are opposite, lance-shaped, and about one-fourth of an inch long (Pl. XI, *b*—lowermost pair). The primary leaves, those that succeed the seed-leaves, are similar to the latter in form, and like them also they are widely spread and more or less bent downward. The still shorter, spreading, sharp-pointed, scalelike leaves produced next are somewhat similar in form to those on adult trees, and appear at the end of the first or second year's growth. Leaves produced a year or two later are like those of adult trees.

The wood of western red cedar is very soft and brittle, and has a strongly aromatic odor. It is the lightest in weight of all the coniferous woods in the Rocky Mountain region, a cubic foot of seasoned wood weighing only about 23½ pounds. When freshly cut, the thin layer of sapwood is whitish and the heartwood is a dull, slightly reddish brown, this tinge being lost by gradual exposure to the light, and replaced by a yellowish brown. The annual layers of growth vary in thickness from moderately wide to narrow. The straight grain of this wood renders it easy to split and its soft texture makes it one of the easiest to work. Great durability under all sorts of exposure is one of its most important commercial qualities. Large logs have lain half buried in wet ground for over 50 years with but little decay of the heartwood. On account of its durability and the large clear cuts obtainable, western red cedar is very extensively used for shingles, as well as for other commercial purposes requiring large dimension pieces. It is also much used in combination with Douglas fir in the manufacture of doors. Young timber

supplies large quantities of telegraph and telephone poles, as well as light-traffic railway ties and posts.

OCCURRENCE AND HABITS.

Western red cedar is confined almost entirely to regions of abundant precipitation and atmospheric humidity, and chiefly also to wet or constantly moist situations (Map No. 8). Occasionally, however, it occurs on moderately dry slopes and warm exposures, but here it is always stunted. In the Rocky Mountain region western red cedar occurs mainly at elevations between about 2,000 and 7,000 feet, the largest and best-formed trees occurring below 5,000 feet, mostly small trees or shrublike forms being found above this level. Only shrubby growths occur in the highest places. The tree generally grows on moist flats, river bottoms, benches, gentle slopes, in and about swamps and wet, springy places, and in cool, moist gulches and ravines. Abundant soil moisture is on the whole more important than quantity or quality of soil; both are, however, essential for the best growth. Western red cedar forms dense pure stands of only limited extent, the formation of small pure patches and groups being especially characteristic. These growths are usually interspersed or otherwise mingled with western hemlock, Douglas fir, lowland white fir, western white pine, western larch, lodgepole pine, Engelmann spruce, and western yew. Its most frequent associates are lowland white fir and Engelmann spruce.

Western red cedar is in general very tolerant of shade. This quality varies, however, with age, altitude, latitude, amounts of soil and atmospheric moisture, and climatic conditions. The tree grows well in dense shade during seedling and early pole stages of life, and may even reach maturity and old age under constant shade; but rapidity and fullness of growth are retarded in proportion to the density of shade; for although a high degree of shade is tolerated without retarding growth during early life, it is not required in middle and later life. Tolerance is greatest under the best conditions for growth and toward the lower limits of the tree's vertical range. Here it maintains a dense crown cover throughout life and commonly forms an understory, alone or with lowland white fir, western white pine, and other species. The density of pure (limited) stands of seedlings and later young growths is so great as to exclude all intolerant, and often some tolerant, associates. Compared in tolerance with other conifers of its range, western red cedar ranks with Tsuga mertensiana, Chamæcyparis nootkatensis, Picea engelmanni, and Taxus brevifolia.

Thuja plicata is a prolific seeder, specially heavy seed production occurring at intervals of two or three years. The seed has a rather high rate of germination but only transient vitality. It falls from

the ripe open cones quickly and is easily disseminated by wind, usually germinating the autumn it is shed, and the seedlings establishing themselves before winter. Germination is abundant and best on moist duff, litter, moss, decayed logs, stumps, etc., both in the open and in the densest shade, where seedlings hold their ground with remarkable power. The tree does not reproduce itself readily where frequent fires have destroyed the ground cover or forest cover to such an extent that soil moisture is materially reduced. Considerable quantities of the seed are eaten by squirrels.

LONGEVITY.

Western red cedar is a slow-growing tree and the extreme age attained is at present imperfectly known, chiefly because the centers of the largest trees cut are usually decayed, thus preventing an accurate count of the annual rings of growth. It may, however, be regarded as very long-lived. Trees 24 to 40 inches in diameter are from 200 to 510 years old. Some of the largest trees are unquestionably from 800 to 1,000 years old.[52]

FAMILY RELATIONSHIPS OF YEW TREES.[53]

The trees and shrubs which belong to the family Taxaceæ (yews or yewlike trees) differ fundamentally from the true cone bearers, Coniferæ, in producing male flowers on one tree and female flowers on another, flowers of both kinds very rarely occurring on different parts of the same tree. The conifers usually bear male and female flowers on the same tree, each sort being on different branches or parts of them.[54]

The leaves of Taxaceous plants are evergreen, flat, narrowly lance-shaped, and appear to grow (in our native species) in spreading lines on two opposite sides of the branches (Pl. XIII). The fruits differ from those of conifers in being almost or entirely enveloped in a pulpy covering. In the case of the yews of this group it is a small, berrylike, bright-colored cup (Pl. XIII, *a*), the hard seed being embedded in a juicy, sticky outer pulp.

In the case of other members of the family the covering of the fruit is firm, practically complete, and similar in appearance to an olive.[55]

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[52] See footnote No. 51, p. 36.

[53] The class relationship of the yew trees is briefly discussed in Forest Service Bulletin No. 207, The Cypress and Juniper Trees of the Rocky Mountain Region, p. 3, 1915.

[54] There are, therefore, fewer seed-bearing individuals among the yews and their allies than among cone-bearers, since only trees bearing female flowers produce seed. Hence, in thinning a stand of Taxaceous timber both male and female trees should be preserved as near to each other as possible if reseeding is expected to take place, for pollen of the male flowers is carried to the female flowers only by the wind. If male trees are distant more than 25 or 30 yards from the female tree, only the strongest wind, blowing at the right time, will effect fertilization.

[55] See fig. 75, Forest Trees of the Pacific Slope, p. 192, 1908.

GENERIC CHARACTERISTICS OF YEW TREES.

The yews belong to a generic group technically known as Taxus. They comprise both trees and shrubs, and while as a group they are very distinct from other Gymnosperms, they are not strikingly distinct as species. For example, there is great similarity in the appearance, structure, and qualities of the wood of different species, and also in the general appearance and form of their foliage and fruit. The characteristics mainly relied upon to distinguish the different species are the shape of the plant, habit of growth, and some minor differences in the form and color of the leaves. The arborescent representatives of this group are world-renowned trees. The wood of one species of yew tree inhabiting Europe, Asia, and Africa was long used by ancient tribes for bows, which were the most important implements of war. In modern archery the wood of this yew tree still holds the highest rank among bow woods.

The yews are evergreen plants, their leaves remaining on the twigs for many years. In form the leaves are flat, narrowly lance-shaped, and sharp-pointed. They are arranged somewhat spirally on the branches, but by a twist at their bases they usually appear to grow in two lines, on opposite sides of the twigs[56] (Pl. XIII).

The male and female flowers of the yews are borne on different trees (exceptionally, flowers of both sexes sometimes occur on different branches of the same tree). Male or pollen-bearing flowers are small, yellowish, budlike bodies produced singly and rather abundantly on the under sides of the branches, while the much less numerous female flowers, small greenish bodies, occur similarly on the branches. The latter develop into fruits (Pl. XIII, *a*), which ripen in one season and usually fall to the ground shortly after maturity. The ripe fruit[57] is a thin-skinned berrylike body, with a bright coral-red, sweetish, mucilaginous pulp, in which a single hard seed appears to be embedded nearly to its point. The seed-leaves are regularly two in number.

The purple or brown bark of yews is very thin. The exceedingly narrow-ringed, dense wood varies in color from a clear rose-red to

[56] The main vigorous shoots of the compact columnar forms of the European yew tree produce leaves with a spiral arrangement, but the ordinary form of this tree bears leaves apparently in two lines.

[57] The seed and leaves of the common European yew tree (*Taxus baccata* Linn.) are known to be deadly poison to human beings and animals when eaten. It is believed that the poison resides in the seed and also in the leaves, from both of which W. Marme obtained by chemical analysis a white, crystalline, poisonous powder named "taxine." Symptoms of poisoning from this plant are semiunconsciousness, cold clammy skin, convulsions, difficult breathing, dilated pupils, and attempted vomiting. (U.S. Dispensatory, sixteenth and nineteenth editions.) While nothing appears to be known concerning the effect of eating the fruit and foliage of our native yews, the very close relationship of these to the European yew tree would indicate that the seed and foliage of our yew trees are similarly poisonous and should, therefore, be avoided. The sweetish pulp of yew fruits is not poisonous, for the mountaineers of northwestern India are said to eat this part of the fruit of Taxus baccata, while cattle of the region are said to eat the foliage and twigs of this plant without injury. It is probable, however, that most browsing animals rarely eat enough of the foliage to get the deadly effect. (Fide Brandis, For. Fl. Brit. Ind. 541.)

TAXUS BREVIFOLIA: FOLIAGE.

a, Twig bearing fruit (attached to under side of branchlet).

dark reddish brown. It is extremely durable under all kinds of exposure and has remarkable elasticity.

The yew trees are of small or medium size, but they live to a great age, specimens of the common European yew tree being said to have attained an age of from 2,000 to 3,000 years. A marked characteristic of the yews is their ability to reproduce themselves by permanent sprouts from cut stumps, and to grow also from cuttings.

Seven different species of yew are now known,[58] two of these occurring in Europe, Africa, Asia, and Japan, and four species in North America. Three of the North American yews inhabit the United States and adjacent portions of Canada, while so far as is now known, a fourth is confined to Mexico. One of our species, a small tree, is confined to Florida; another is a shrub growing in our northeastern States and in adjacent Canadian Provinces; while the fourth species, a small or medium size tree, inhabits our Pacific and northern Rocky Mountain forests, extending northward into adjacent Canadian territory (Map No. 9).

The yews are of very ancient origin. Fruits of Taxus have been found in the European Oligocene, while remains of the European yew tree (*Taxus baccata* L.) have been discovered in the late Miocene of Europe and are also common throughout the Pliocene and Pleistocene of that region. Remains of a shrubby species now living and known as Taxus canadensis Marsh. have been found in the Pleistocene of Manitoba, Ontario, Nova Scotia, Iowa, and Illinois.[59]

WESTERN YEW.

Taxus brevifolia Nuttall.

COMMON NAME AND EARLY HISTORY.

Taxus brevifolia is little known as a distinct species except to botanists and foresters. Woodsmen within its natural range are familiar with it, but they call it simply "yew." The common name western yew, suggested here, is desirable because it serves to avoid confusion of this tree with the two other yews that occur in the United States.

The earliest record we have of the discovery of western yew is by the Scotch explorer David Douglas, who found it in 1825 on the lower Columbia River, Oreg. William Jackson Hooker, an English botanist, published the first account of it in 1839, but he treated it as a form only of the European yew, Taxus baccata Linneus, which became known to botanists in 1753. It remained for Thomas Nuttall to

[58] Elwes and Henry (The Trees of Great Britain and Ireland, I, 100, 101, 1906) have reduced six of these to varietal rank under Taxus baccata.

[59] Fide Dr. Edward W. Berry, paleontologist Johns Hopkins University, Baltimore, Md.

distinguish and to give this northwestern tree its present technical name, Taxus brevifolia, which was published in 1849.[60]

DISTINGUISHING CHARACTERISTICS.

The western yew is a small tree from 20 to 30 feet in height and from 6 to 12 inches in diameter, occasionally attaining a height of from 40 to 75 feet and a diameter of from 18 to 30 inches. The largest trees occur in the Pacific slope region. As found in the Rocky Mountain region, western yew rarely equals 25 feet in height, and frequently it is only a shrub. The trunks are straight and conical, but conspicuously ridged and fluted as if by an infolding of the surface. Diameter growth is often very eccentric (larger on one side of the pith than on the other). Except in the case of large old trees, the crown has an open conical form and extends nearly or quite to the ground, the slender branches standing out straight and often drooping somewhat, while from their sides and extremities very slender branchlets hang down, giving the tree a weeping appearance. This latter habit is strongly marked in trees growing partly or wholly in the open, because here the densely leafy branchlets are very much more numerous than on trees growing in deep shade. The crowns of old trees are usually rounded and often unsymmetrical.

The purplish bark is conspicuously thin, rarely over one-fourth of an inch thick, and composed of thin, paperlike, easily detached scales, beneath which the newer unexposed bark is a clear rose-red or purple-red.

The deep yellow-green leaves (Pl. XIII), from one-half to three fourths of an inch long, are soft to the touch, and much paler on their under sides than on the upper; their yellowish slender stems are about one-sixteenth of an inch long. Leaves produced each year remain on the trees in a green and functional condition for about five years; occasionally, a few green leaves from 6 to 9 years old are found here and there on branches.

The bright coral-red fruit (Pl. XIII, *a*) is ripe in September and begins to fall during October. Birds often eat the fruit for its sweetish mucillaginous covering, but the hard-shelled seeds are unaffected by digestion. The attractiveness of the fruit to birds serves, therefore, as an important means of disseminating the seed, which otherwise would not be carried far from the parent trees. The short, flat,

[60] According to Veitch (Man. of Coniferæ, ed. 1, p. 305, 1881) Taxus brevifolia was first introduced into cultivation in European gardens in 1854 by Veitch & Sons through their collector, William Lobb. But in the "New and Greatly Enlarged Edition" of Veitch's Manual of Coniferæ (p. 143, 1900) the statement is made that Taxus brevifolia was introduced into British gardens in 1854 by William Murray. To what extent this yew has been planted in European gardens and how well it has succeeded there appears to be imperfectly known. Veitch (l. c.) says the tree is still exceedingly rare in British gardens. Elwes and Henry (The Trees of Great Britain and Ireland, I, 108, 1906) state that they know of no specimens of large size in England.

pointed seed-leaves are two in number. Nothing can be said now regarding the subsequent early growth and characteristics of seedlings, which have not been fully studied.

Taxus brevifolia produces extremely narrow-ringed, clear, rose-red heartwood, which, with exposure to the light, gradually becomes a duller red, the thin layer of sapwood being a very pale yellow when freshly cut. The wood is dense, rather heavy, and when thoroughly dry a cubic foot of it weighs nearly 40 pounds. Thoroughly seasoned wood of this yew is remarkably durable, even in an unprotected state, when used in contact with earth or in water. Owing to the scarcity of the trees, however, the wood is of little commercial importance. Great durability and elasticity render it useful mainly for such articles as canoe paddles and bows; and its attractive color makes it suitable, also, for small cabinet work. As a forest tree, it is only of very secondary importance, both because of its rarity and the fact that larger and more generally useful timber trees grow abundantly in the same range. On account of its remarkable tolerance of dense shade it can, however, assist in forming low protective cover in moist coves and canyons and at the heads of mountain streams.

OCCURRENCE AND HABITS.

Taxus brevifolia grows near the margins of low mountain streams, on moist flats and benches, in deep ravines and coves in rich rocky or gravelly soils, or sometimes in rather dry soils of slopes and ridges. Its altitudinal range is from about 2,000 to 8,000 feet. Tree forms of it occur chiefly below 5,000 feet, while shrubby forms are found mostly above this elevation (Map No. 9).

Western yew occurs only in small groups or scattered singly, mainly as an undergrowth, with western white pine, lowland white fir, western larch, Engelmann spruce, lodgepole pine, and western red cedar. It is a frequent, and often the only, undergrowth with the western red cedar. In its Pacific slope range western yew is often associated also with Chamæcyparis nootkatensis and occasionally at high elevations with Pinus albicaulis.

Like all of the other representatives of this group, the western yew is exceedingly tolerant of shade throughout its life. However, when growing under dense shade, it maintains a comparatively open crown with rather thin foliage, partial shade or full light producing a much more densely branched crown and fuller foliage. The contrast between trees grown in dense shade and those grown in full enjoyment of sunlight is very striking.

Western yew is a fairly prolific seeder, but at rather irregular intervals. The vitality of the seeds is persistent, and the percentage of germination is moderately high, being from 50 to 60 per cent.

Seedlings occur, however, only occasionally, and most frequently in deep shade on wet moss and decaying wood. The generally scattered occurrence of this species and the fact also that only female trees bear fruit, which is much eaten by birds, doubtless account for the sparse, often rare, occurrence of seedling growth.

LONGEVITY.

The extreme age attained by the western yew has not been determined. Its growth in height and diameter is very slow, particularly under deep shade; but even here the tree maintains itself most persistently, indicating that it is long-lived. Comparatively few sound trees of even moderately large size appear to have been studied. Trees 6 inches in diameter are from 75 to 90 years old, while trees from 12 to 20 inches in diameter are from 140 to 245 years old. The largest specimens are believed to be at least 350 to 375 years old. Owing to the fact that the largest trees are so often punky at the center it will be difficult to determine satisfactorily the extreme age of this yew.

KEY TO GENERA AND SPECIES.

Leaves needle-shaped and borne singly:
- Bark of the trunk very thin, smooth or loosely scaly and purple.. *Taxus brevifolia*
- Bark of the trunk rough; thick and furrowed, or thinnish and with firm scales—
  - Leaves with distinctly formed delicate stems—
    - Cones ¾ to 1¼ inches long; flat leaves in 2 thin lines..... *Tsuga heterophylla*
    - Cones 1½ to 3 inches long; rounded leaves not in lines..... *Tsuga mertensiana*
  - Leaves contracted at the base but without distinctly formed stems—
    - Cones bearing conspicuous, 3-pointed bracts..... *Pseudotsuga taxifolia*
  - Leaves in brushlike clusters of from 12 to 40—
    - Cones about one-half an inch long and without exserted bracts.. *Larix laricina*
    - Cones 1 to 2 inches long and with exserted bracts—
      - Trunk bark thick, from 3 to 6 inches thick and deeply furrowed, *Larix occidentalis*
      - Trunk bark thin, from one-half to three-fourths of an inch thick and slightly furrowed..... *Larix lyallii*

Leaves scalelike, borne in pairs and closely overlapping each other:
- Cones borne near the ends of twigs; seeds winged on two sides..... *Thuja plicata*
- Cones borne at the ends of twigs; seeds winged at one end..... *Libocedrus decurrens*

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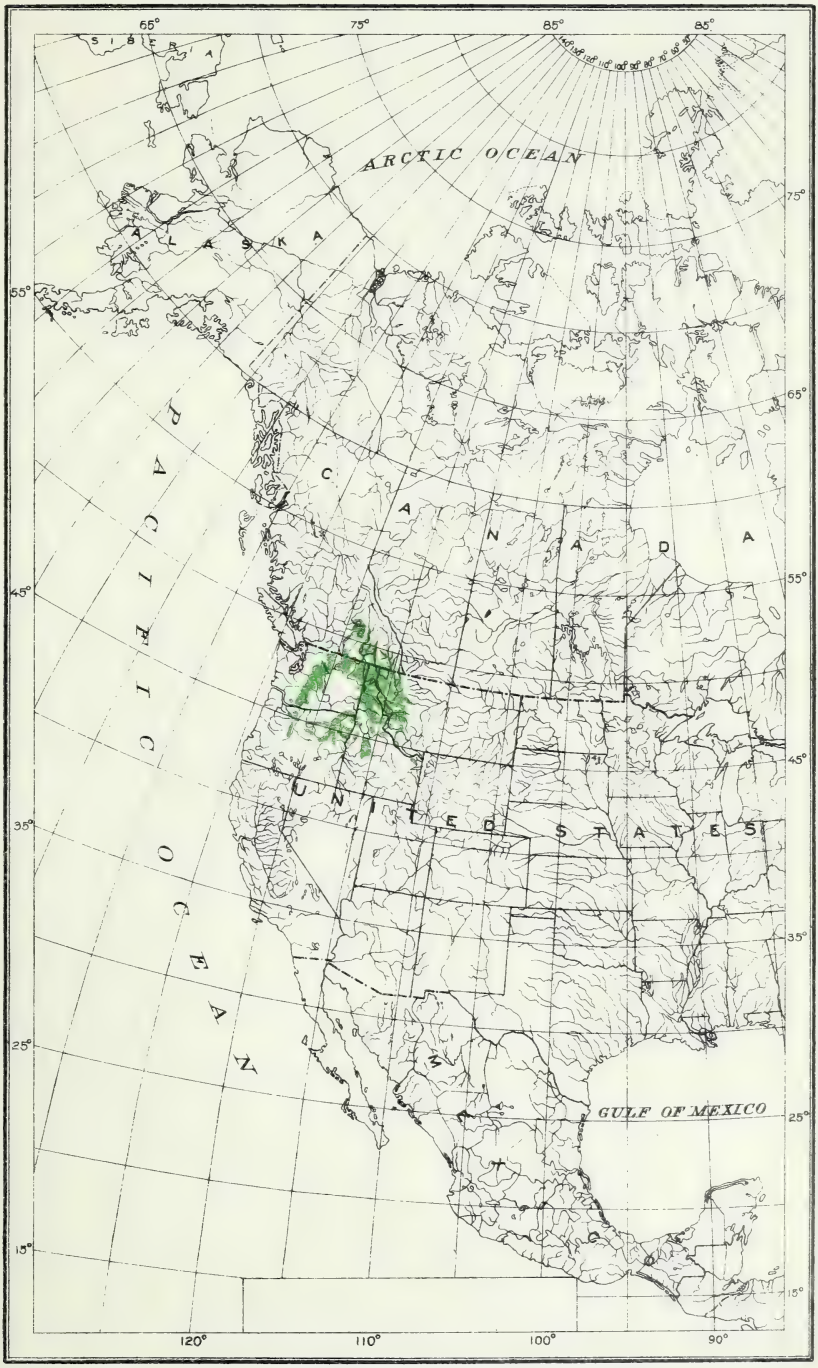

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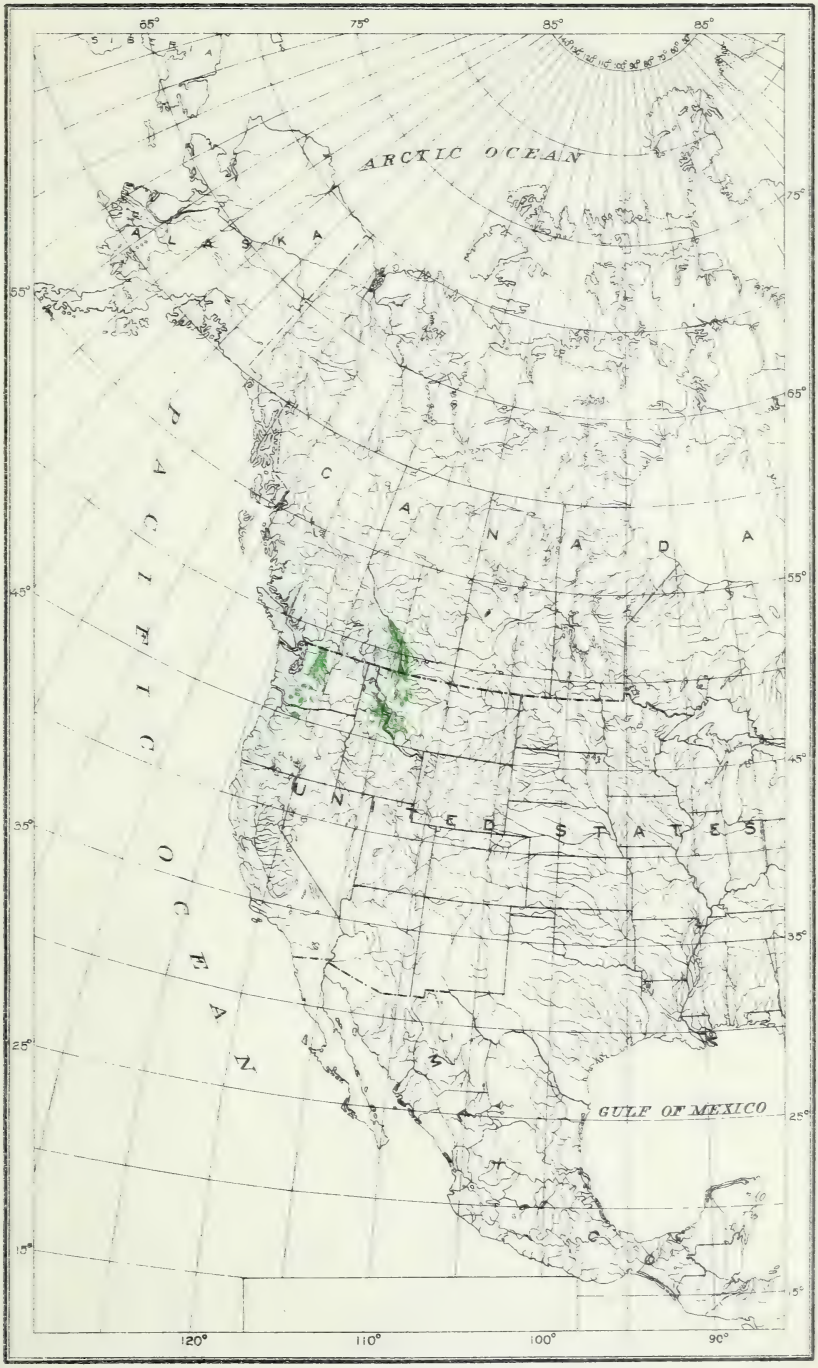

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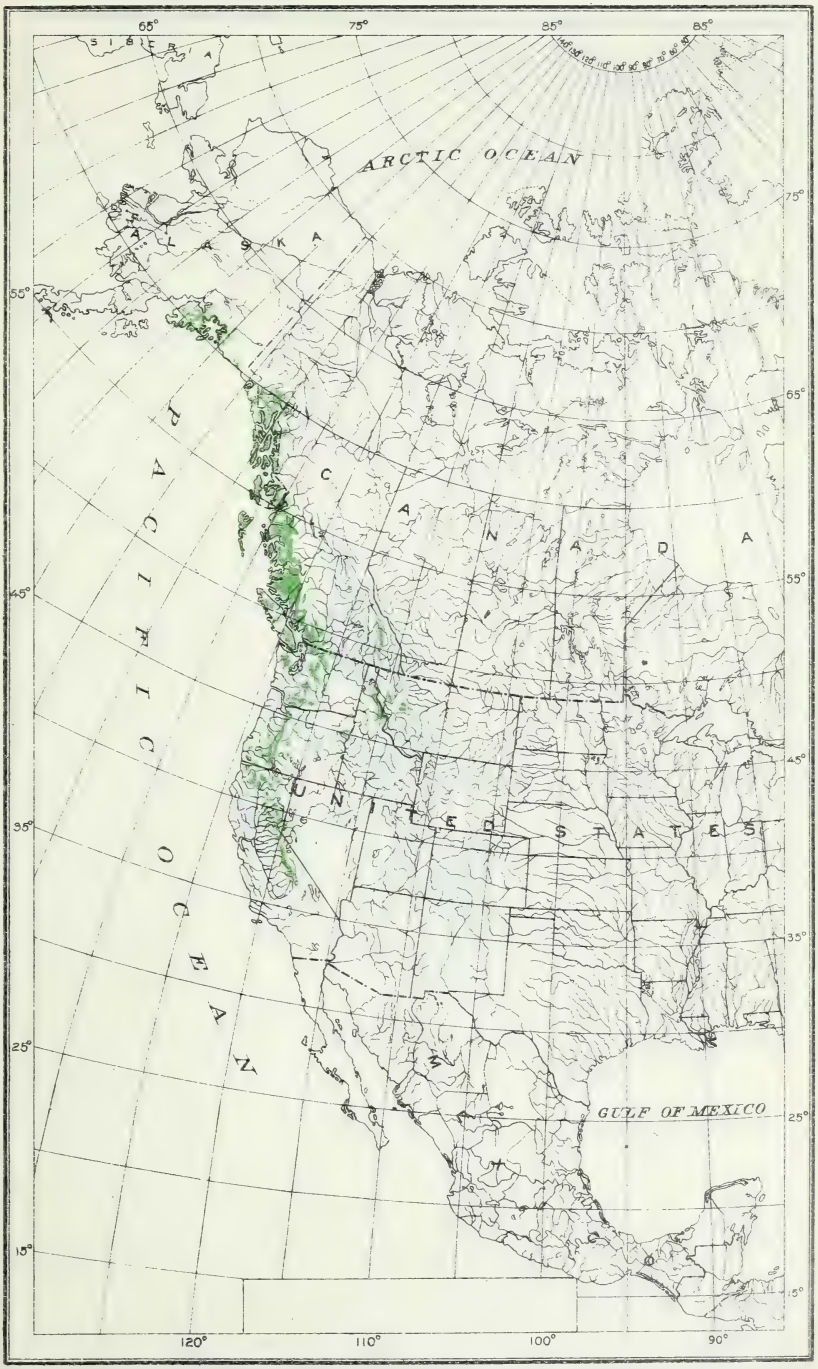

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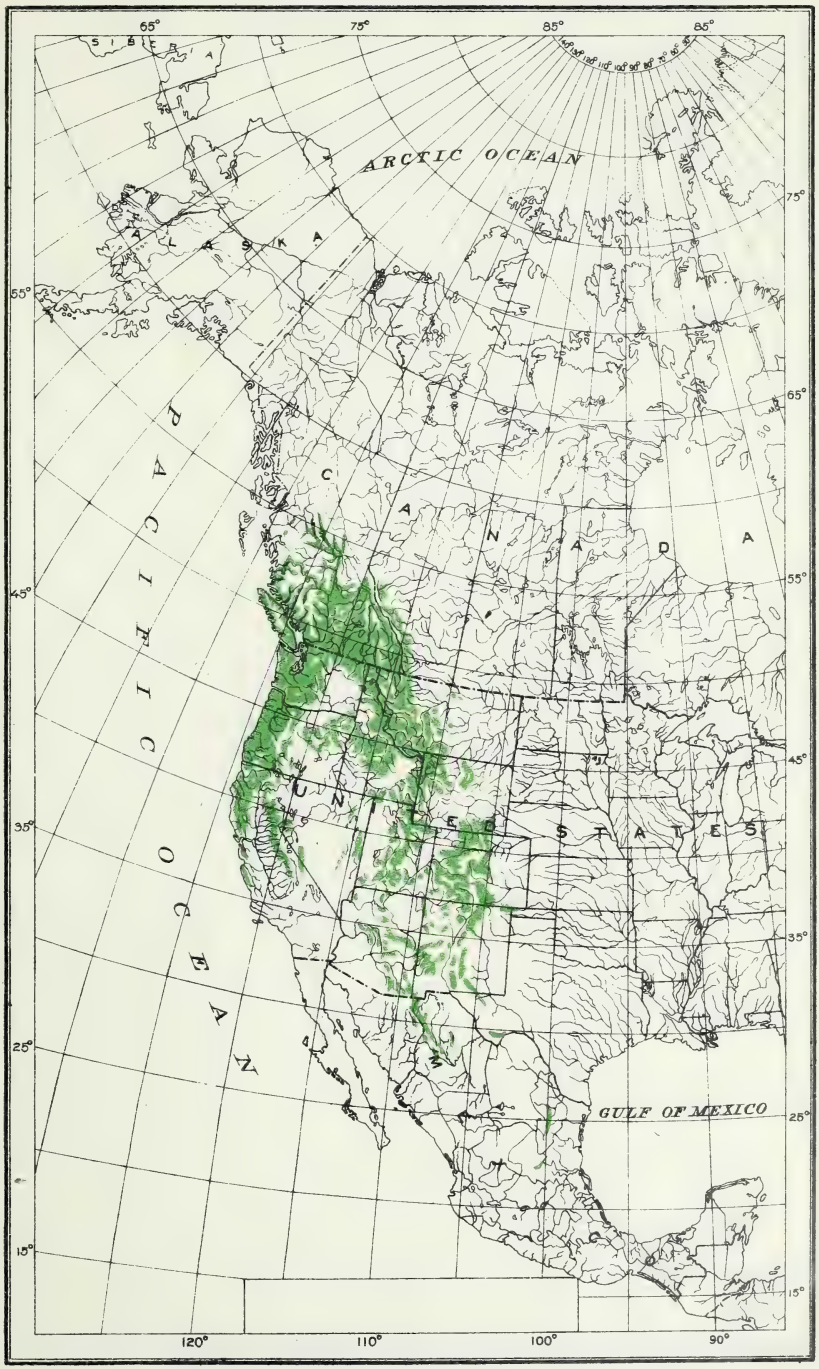

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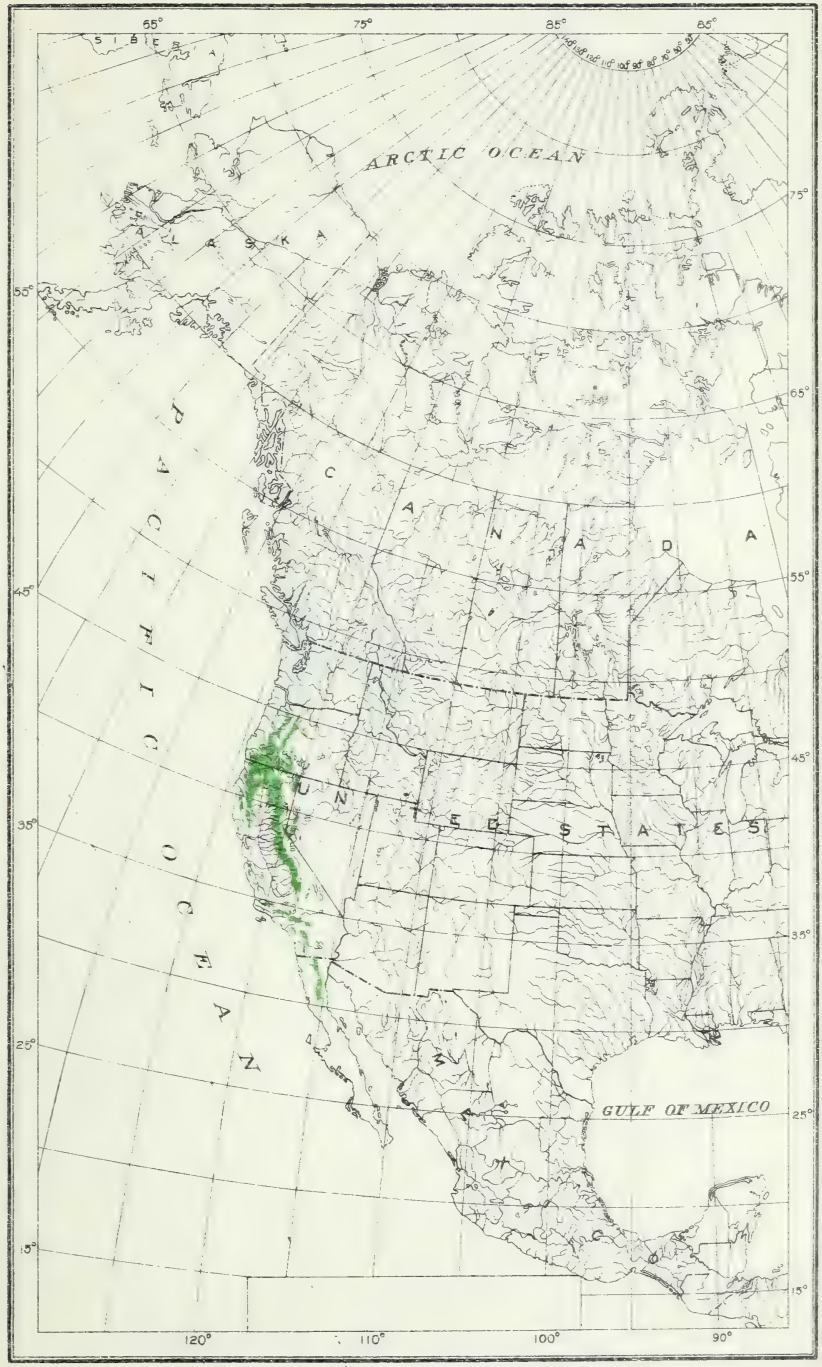

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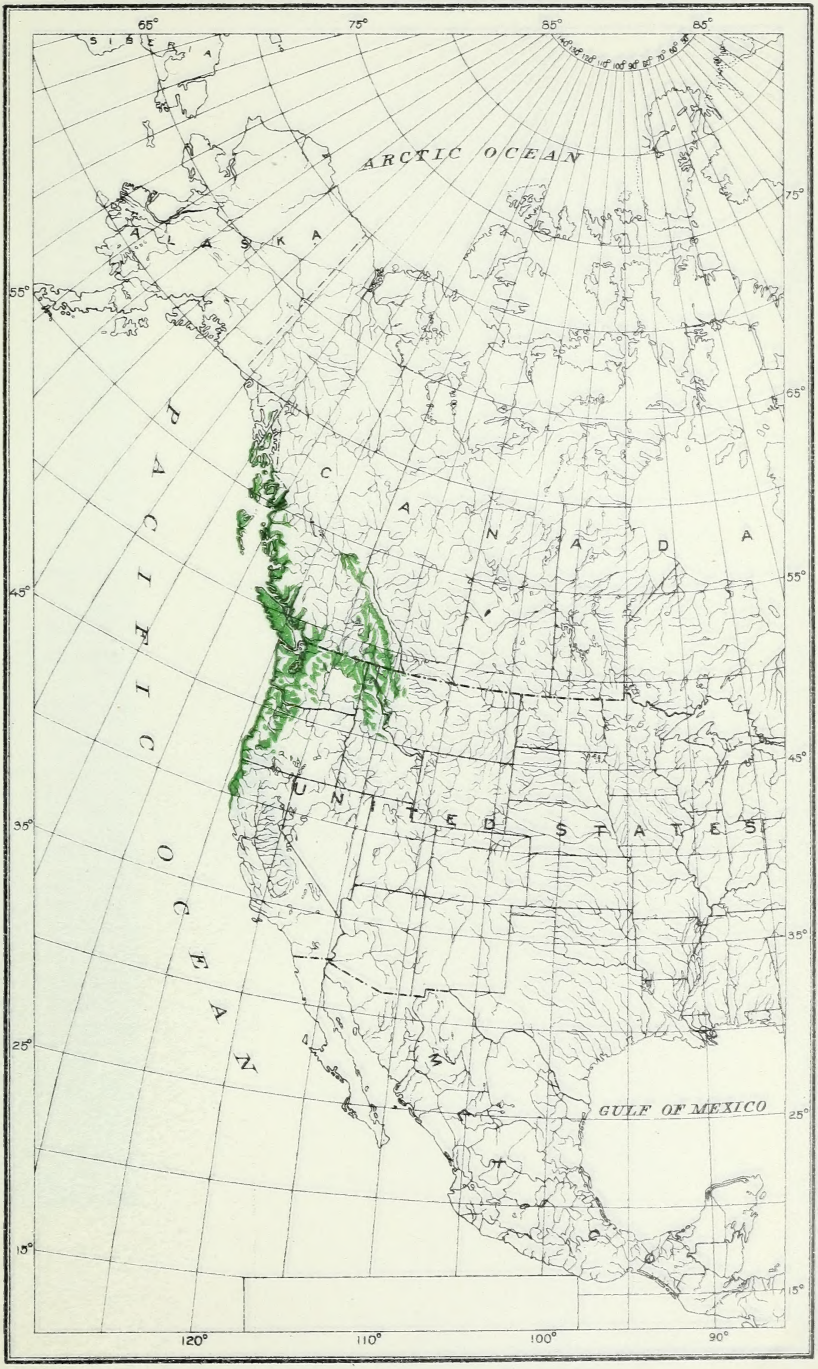

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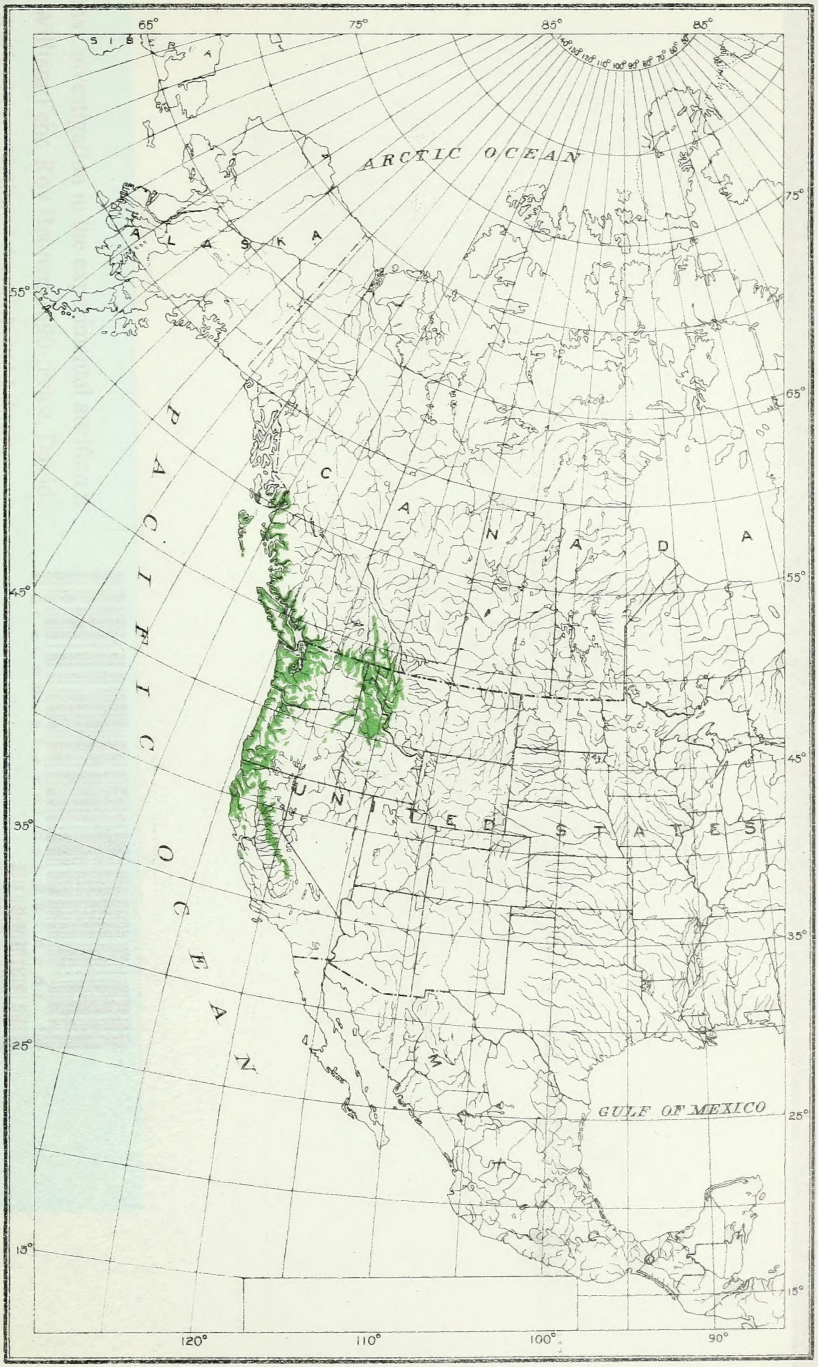

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